Greensboro Urban Area 2003 Congestion Management System

Greensboro, NC

Prepared for

Greensboro Urban Area Metropolitan Planning Organization

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FINAL REPORT

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EXECUTIVE SUMMARY

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA 21) established the Congestion Management System (CMS) as a necessary part of the transportation planning process. As per the regulations of the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) it is required that all Transportation Management Areas (TMA), urbanized areas with a population greater than 200,000, develop and implement a CMS. On July 8, 2002 US Bureau of the Census officially designated the City of Greensboro, North Carolina, population 223,891, as a TMA. This report is the first CMS produced for that area. The GUAMPO area is shown in Map 1.

An effective congestion management system can serve many varied functions to a regional transportation planning organization. To the technician, the CMS can be a comprehensive collection of all regional traffic and roadway data. To the decision-makers, the CMS can be an invaluable tool in setting priorities for both the short term and long term planning horizons. The vision of the Greensboro CMS is to expand the current planning process with a new tool to help examine the current roadway network, identify causes of congestion, and explore options for reducing congestion. In addition to examining capacity constraints, methodologies for improving system efficiency and providing modal choices will also be identified.

CMS Roadway Network

Only roads that are considered regionally significant were selected for study in the CMS. The network selected for study includes 826 centerline miles of existing roads and 55 centerline miles of new roads programmed for construction by 2010. Based on those centerline miles, the existing roads included in the network constitute approximately 2,080 lane-miles of vehicle carrying capacity while the network for 2010 presents a total of approximately 2,400 lane-miles of vehicle carrying capacity. Map 1 shows the roadways that were included in the CMS analysis network.

Data

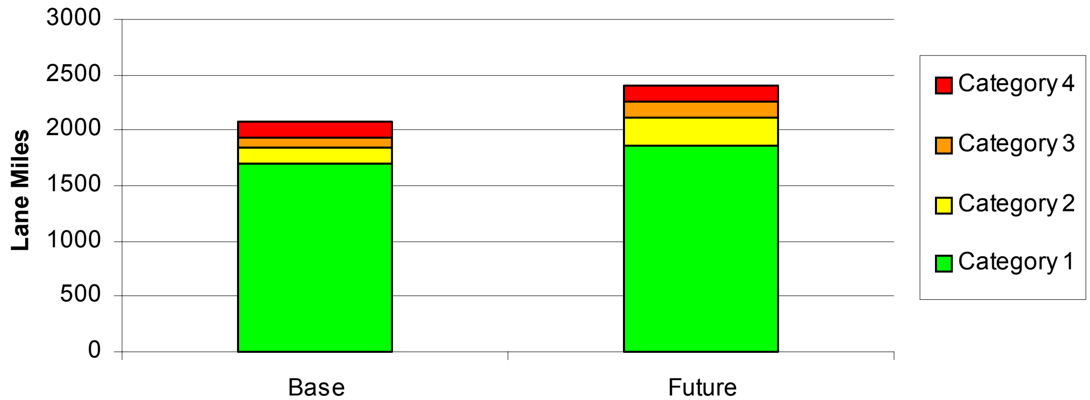
Traffic data was gathered from both the City of Greensboro and the North Carolina Department of Transportation for study in the CMS. The City of Greensboro provided traffic signal timing data and peak hour traffic counts at all of the signalized intersections in the urbanized area as well as daily traffic volumes at locations throughout the region. Average annual daily traffic was gathered from NCDOT to supplement the data provided by the City of Greensboro. The traffic signal timing data were utilized to more accurately estimate the capacities of the roadways in the region.

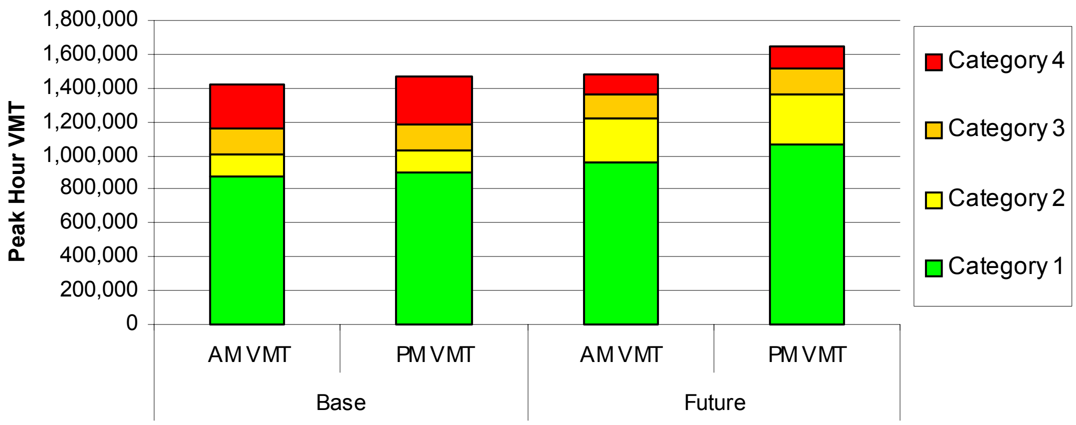
Capacity Analyses

The analyses indicate that the majority of the roadways in the network operate at acceptable levels and that the majority of the roadways in the region will continue to operate at acceptable levels in 2010. The table and chart below summarize the analysis results by existing and future V/c category using lane-miles as the measure.

Total Lane Miles and Vehicle Miles Traveled

	Lane Miles	AM VMT	PM VMT
Base	2076.6	1,426,755	1,467,157
Future	2405.0	1,481,040	1,645,720
Change	328.4	54,285	178,563





Management Systems
The City of Greensboro has been very proactive in implementing management strategies aimed at increasing the efficiency of the transportation system without adding additional capacity to the roadways. The City currently has already implemented the following management strategies:

- Expansion of Transit Operations – The City has planned a major expansion of the local transit system to double the ridership annually from two million trips to four million trips. In addition, the Piedmont Authority for Regional Transportation (PART) has planned to implement a regional transit system that will connect transit stations in Greensboro, Winston-Salem, and High Point. Five park and ride lots are also programmed as part of the regional transit system.
- Advance Traveler Information System (ATIS) and Variable Message Signs (VMS) – Views from roadside traffic camera, information on road closures, and other essential traffic data is provided on the City's website. Variable message signs are already in place along the existing major interstate corridors in the region. The VMS system will be expanded to the new Urban Loop also.

- Updated Signal System – The City has programmed a citywide signal system upgrade to provide more efficient operation of the traffic signals in the region. The new system will be monitored from a new central management center.

Other than expanded transit systems and park and ride lots, the GUAMPO has not implemented any other transportation demand management strategies (TDM) to reduce the number of single occupant vehicles on the roads. Employer based TDM strategies such as ridesharing and ride-matching programs could at minimum address traffic congestion local to the employer sites. The success of these programs depends on the cost of the programs to the user and what incentives can be leveraged to attract and maintain a high number of users.

Pedestrians and Bicyclists
In addition to improving the efficiency of the roadways in the region, the City of Greensboro has also made mobility and access for pedestrians and bicyclists a regional priority as well. Statements in the Greensboro Comprehensive Plan, the adoption of the Greensboro Walkability Policy, the Pedestrian Safety Program, and the Sidewalk Program are all evidence of the commitment City has made for pedestrians and bicyclists. The goal of these policies is to improve safety and awareness of pedestrians and bicycle through the provision of safe and accessible facilities throughout the City.

System Monitoring
The GUAMPO transportation system is currently monitored jointly by the Greensboro Department of Transportation and the North Carolina Department of Transportation. Through the joint efforts of these agencies vehicle crash data, average annual daily traffic data, and peak hour traffic data is collected and maintained in databases for historical tracking. The Greensboro Department of Transportation currently collects the peak hour traffic data at signalized intersections. The NCDOT collects average annual daily traffic counts at locations throughout the region and maintains a database of all vehicle collisions in the region. The data collected by NCDOT is accessible and provided to GDOT upon request.

Vehicle travel speed and travel time are the most ideal measures of the efficiency of a transportation system. Current data collection programs of GDOT and NCDOT do not include the collection of travel speeds in the urban area. While the traffic data collection programs are also vital to system monitoring for planning purposes, travel speeds will give a more complete picture and clearly identify the inefficiencies in the transportation system.

Recommendations
The GUAMPO has been very proactive in implementing policies and programs to more efficiently manage the transportation system in the region, however there are areas where improvements can be made.

- Expand the system monitoring efforts to include the collection of peak hour vehicle travel speeds. Peak hour travel speeds are the true indicator of system efficiency.
- Develop a transportation demand management strategy (TDM) focusing on the larger employers in the region. Successful transportation demand management programs will reduce local parking demand and traffic congestion. TDM programs could focus on ridesharing and the use of transit.

- Accelerate funding to implement the regional signal system upgrade and construction of the traffic management center.
- Accelerate funding to implement improvements to the local and regional transit system including the construction of park and ride lots.
- Update the CMS as the initial stage to every LRTP update.
- Continue to collect roadway geometric data for new roads and expand traffic volume data collection to cover more of the CMS network. The coverage of data collection should be expanded in concert with the expansion of regional transportation planning priorities.
- Collect vehicle travel time data on roadways in the CMS network. It is recommended that the MPO first determine the level of output desired from a travel time data collection system. The next step is to then decide the level of technology required to meet those needs. The level of technology required will dictate the financial commitment necessary. Some of the more robust systems currently in application in other areas utilize GPS technologies, while others require much less advanced data collection methods but the tradeoff will be the usefulness of the collected travel time data.
- Coordinate CMS development with the congestion and safety related intersection improvement programs of the City of Greensboro and NCDOT.

In addition to implementing new efforts, it also recommended that current efforts continue:

- Encourage NCDOT to continue the IMAP motorist assistance program on the existing interstates in the region and expand the system onto the new interstates as they open to traffic.
- Continue the joint efforts with NCDOT to monitor the regional transportation system.
- Continue expanding and enhancing the management systems that are already in place.

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1.0 INTRODUCTION

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA 21) established the Congestion Management System (CMS) as a necessary part of the transportation planning process. As per the regulations of the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) it is required that all Transportation Management Areas (TMA), urbanized areas with a population greater than 200,000, develop and implement a CMS. On July 8, 2002 US Bureau of the Census officially designated the City of Greensboro, North Carolina, population 223,891, as a TMA. This report is the first CMS produced for the region.

The vision of the Greensboro CMS is to expand the current planning process with a new tool to help examine the current roadway network, identify causes of congestion, and explore options for reducing congestion. In addition to examining capacity constraints, methodologies for improving system efficiency and providing modal choices will also be identified. Figure 1 shows the GUAMPO area including the roadways that were included in the CMS analysis network.

Figure 1: GUAMPO Area Map

2.0 BASIS FOR ANALYSIS

2.1 ROADWAY NETWORK

The Greensboro Urban Area Metropolitan Planning Organization (GUAMPO) is the federally designated agency responsible for transportation planning in the Greensboro Urbanized Area. The City of Greensboro Department of Transportation is the Lead Planning Agency (LPA) for the GUAMPO. The current Metropolitan Area Boundary (MAB) encompasses not only the City of Greensboro, but also much of Guilford County. Guilford County, and the Triad Region in general, is a rapidly growing area in the heart of North Carolina. As the geographic center of the Triad, it is expected that as the region continues to grow, Greensboro and Guilford County will see a great deal of additional traffic as part of that growth.

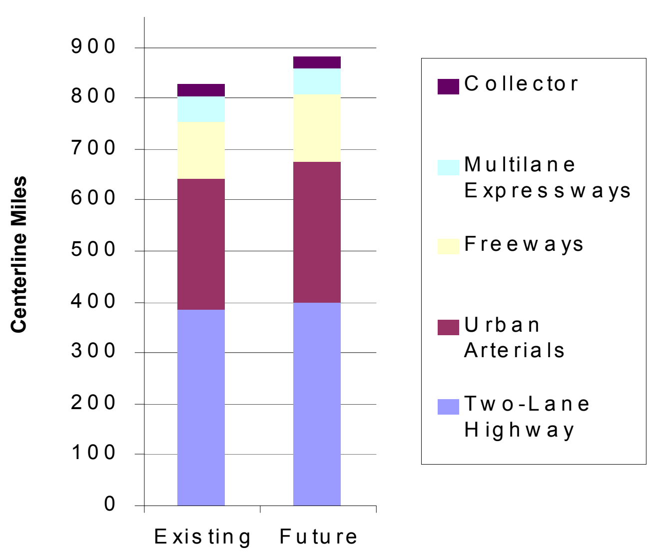
The base year CMS network is similar to the currently adopted GUAMPO Thoroughfare Plan. This network includes all interstates, expressways, and principal and minor arterials within the GUAMPO MAB. In addition, streets in the central business district were added, as they will have a direct impact on the City of Greensboro transit system and could begin to become congested in future years. These additions yielded a base network of approximately 826 centerline miles and 2,080 lane miles.

For the determination of the future year network, the 2004-2010 editions of both the State and Metropolitan TIP were consulted. Projects programmed in the TIPs to be complete by 2010 were added to the future year CMS network. No projects from the "North Carolina Moving Ahead" program were included as they were expected to have no significant effect on capacity. These additions resulted in an addition of 55 centerline miles and 330 lane miles yielding a final network with 881 centerline miles and 2,400 lane miles. **Table 1** and **Figure 2** summarize the centerline miles for both existing conditions and future conditions. For a list of additions included in the future year of the CMS Network, see **Appendix A**.

Table 1: Centerline Miles

Facility Type	Existing	Future
Two-Lane Highways	386.7	399.8
Urban Arterials	256.6	276.5
Freeways	110.5	132.7
Multilane Expressways	50.6	50.6
Collectors	22.1	21.9
Total Centerline Miles	826.5	881.6

Figure 2: Existing and Future Centerline Miles



2.2 ROADWAY CAPACITIES

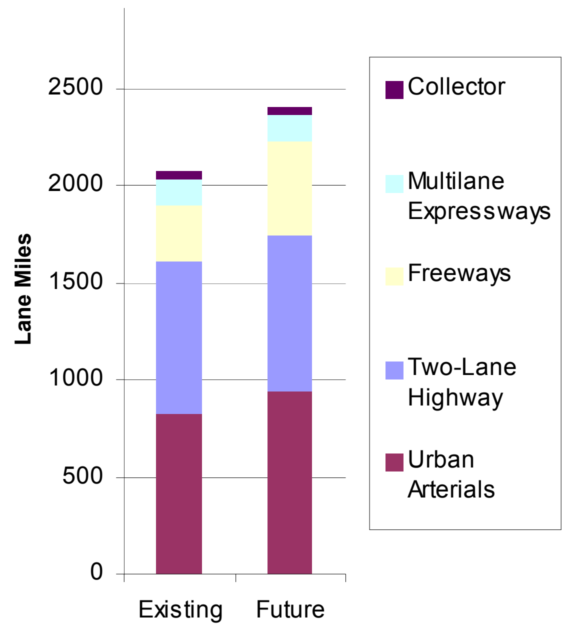
Capacities were determined using 2000 Highway Capacity Manual techniques. For all segments the ultimate, or LOS E, capacity was used. Use of the ultimate capacity removed many of the variables associated with capacity determination. For most facility types, capacity could be determined by the number of lanes, g/c ratio, and the treatment of medians and left-turn lanes. As g/c ratios were not available in all areas, assumptions were made based on facility type. To examine the specific capacity calculations and the assumptions associated with each facility type, see **Appendix B**. **Table 2** and **Figure 3** summarize the lane miles for each facility type for base and future conditions.

In specific areas, where g/c assumptions did not provide an accurate prediction of ultimate capacity, actual g/c ratios were used to determine capacity.

Table 2: Lane Miles and Facility Type

Facility Type	Existing	Future
Two-Lane Highways	781.6	799.9
Urban Arterials	829.2	939.7
Freeways	286.8	488.3
Multilane Expressways	131.3	131.3
Collectors	47.7	46.2
Total Lane Miles	2076.6	2405.0

Figure 3: Lane Miles and Facility Type



2.3 TRAFFIC CONDITIONS

Where possible, the volumes used for the base year were the peak hour counts provided by the City of Greensboro. Where no peak hour counts were available, 2002 AADT data provided by NCDOT counts were adjusted using a peak to daily factor (k-factor) to estimate peak hour traffic volumes. A k-factor of 0.1 was used unless a more accurate k-factor could be determined using a combination of the peak hour counts from Greensboro and AADT counts from NCDOT.

The construction of the Southern Urban Loop and a large portion of the Western Urban Loop are expected to have a major effect on traffic volumes and patterns. Because of this, the use of historical traffic growth patterns is not an accurate way to predict future traffic volumes. For this reason the 1994 Triad Regional Travel Demand Model (TRTDM) was used to predict 2010 volumes.

2014 was the closest year for which a prediction of socio-economic data was available for the TRTDM. In an effort to predict accurate traffic patterns, the 2014 roadway network was revised to match the 2010 CMS network. A model run was made using the 2014 socio-economic data and the revised 2014 network. The predicted 2014 volumes were then factored proportionally to the growth in VMT predicted by the 1994 TRTDM to obtain daily 2010 traffic volumes. Peak hour volumes were then calculated using a k factor of 0.09 for the A.M. peak hour and 0.1 for the P.M. peak hour.

3.0 CAPACITY ANALYSES

3.1 METHODOLOGY

Volume to capacity ratio was used as the measure of congestion instead of the Highway Capacity Manual Level of Service (LOS). The 2000 Highway Capacity Manual (HCM), in a shift from previous editions, has updated the LOS calculation techniques. Whereas in previous editions LOS was closely related to volume it is now more closely related to speed and control delay. The City of Greensboro does not currently collect speed and travel time data. For this reason using the HCM LOS was not a viable method of determining congestion.

The volume to capacity ratio, or v/c ratio, is an effective methodology for determining the functioning level of an individual roadway segment. A v/c ratio of less than one indicates a road segment that has capacity available for additional traffic. A v/c ratio greater than one indicates a road segment in which demand is greater than the capacity available. Generally a v/c ratio less than one indicates consistent, although possibly slower than desired, traffic operations, while a v/c ratio greater than one implies stop-and-go, or highly impeded traffic conditions. To provide a complete picture of the CMS networks v/c ratios were divided into four categories as shown in Table 3.

Table 3: Volume to Capacity Ratio Category Definitions

V/c Category	Volume to Capacity Ratio
1	Less than 0.80
2	Between 0.80 and 1.0
3	Between 1.0 and 1.2
4	Greater than 1.2

3.2 CONGESTION ANALYSIS AND SUMMARY

Roadway congestion index, lane-miles, and vehicle miles traveled were used to summarize the results of the analyses. Lane miles and VMT were summarized according to the V/c categories indicated in Table 3. The summary below first discusses the roadway congestion index for the entire region. Lane-miles and VMT summaries are first presented for the entire CMS network then the subsequent sections summarize lane miles and VMT for the existing roads and new roads planned for construction individually.

Summary of All Roads in the CMS Network

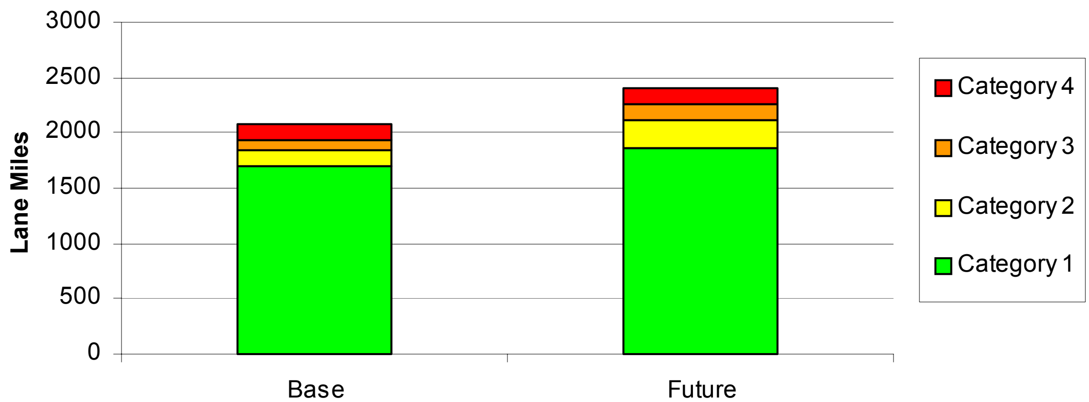
Currently, 83.4 lane miles of the Greensboro roadway network are moderately over capacity and 142.8 lane miles are highly over capacity. This comprises 10.9% of the total analyzed roadway network. In addition to those lane miles over capacity, an additional 151.9 lane miles, or 7.3%, of the roadway network are approaching capacity. This means that with no additional capacity 18.2% of the lane miles in the Greensboro roadway network will be over capacity in the near future.

As per the latest TIP, it is expected that 328.4 lane miles will be added to the Greensboro network. As a result there will be 159.0 lane miles of the roadway network moderately over capacity in 2010 and 137.4 lane miles highly over capacity. Of those 296.4 lane miles, only 103.7 lane miles, or 35.0%, are currently moderately or highly over capacity. Current projects are expected to solve the capacity shortfalls of 174.9 lane miles that have a v/c ratio greater than one in the current year. **Table 4** and **Figure 4** summarize the existing and future lane-miles by each V/c category.

Table 4: Summary of All Lane Miles by V/c

	Base		Future		Change	
V/c Category[1]	Lane Miles	Percent of Total	Lane Miles	Percent of Total	Lane Miles	Percent Change
1	1698.5	81.8%	1861.6	77.4%	163.2	9.6%
2	151.9	7.3%	246.9	10.3%	95.0	62.6%
3	83.4	4.0%	159.0	6.6%	75.6	90.7%
4	142.8	6.9%	137.4	5.7%	-5.4	-3.8%
Total	2076.6		2405.0		328.4	

Figure 4: Summary of All Lane Miles by V/c Category

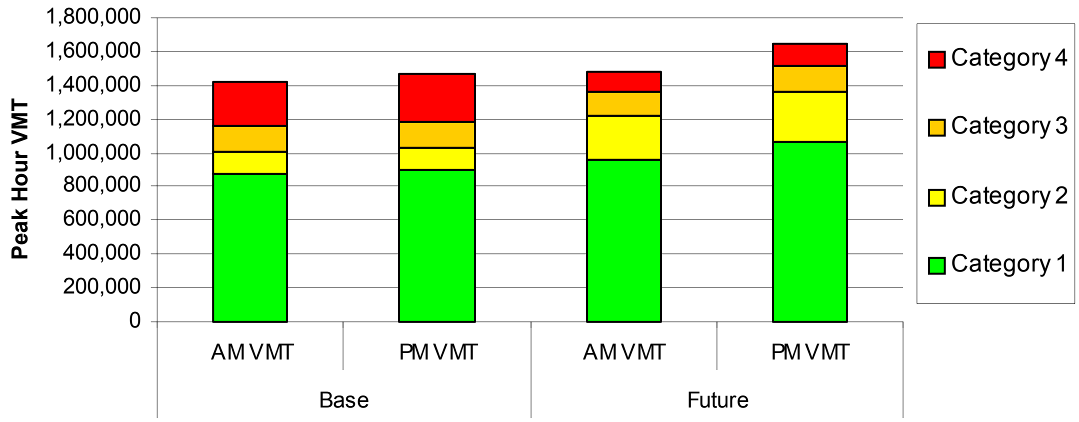


The additional capacity in the future year is expected to have quite an impact on traffic volumes and patterns. While new construction will decrease volumes to under capacity on 192.8 lane miles, 204.3 lane miles will see traffic growth so as to become newly over capacity in 2010. This is an increase of 81.4 lane miles over the current levels, or 4% of the 2002 roadway network. However, while the total lane miles of the network over capacity will increase, the percent of VMT on moderately or highly over capacity roadway will decrease from 30.1% in the base year to 20.0% in 2010. The result of this is a decrease from 404,350 VMT during the P.M. peak hour on moderately or highly over capacity roadways to 329,780 VMT on moderately or highly over capacity roadways in 2010. This means that while total VMT will increase 12.1%, VMT on moderately or highly over capacity roads will decrease 25.1%. **Table 5** and **Figure 5** summarize the existing and future VMT by each V/c category.

Table 5: Summary of All VMT by V/c Category

	Base		Future		Change	
V/c Category[1]	AM VMT	PM VMT	AM VMT	PM VMT	AM VMT % Change	PM VMT % Change
1	881,868	899,457	955,289	1,061,461	8%	18%
2	122,911	127,344	268,925	298,847	119%	135%
3	151,834	155,150	136,288	151,433	-10%	-2%
4	270,142	285,206	120,538	133,979	-55%	-53%
Total	1,426,755	1,467,157	1,481,040	1,645,720	8%	18%

Figure 5: Summary of All VMT by V/c Category



Summary of Existing Roads in the CMS Network

The impact of roadway improvements on existing roads can often become lost when focusing on system-wide measures for all of the roadways in the analysis network. The tables and figures below focus only on the existing roadways and the impact of planned improvements.

Table 6: Summary of Existing Roads By V/c Category

Base V/c Category	Planned for Improvement	Not Planned for Improvement	Total
1	17.9	674.9	692.8
2	5.9	42.8	48.7
3	12.9	18.3	31.2
4	21.5	32.4	53.8
Totals	58.1	768.3	826.5

As shown in Table 6, approximately 85 miles of existing roadway in the CMS network are currently operating in Category 3 and Category 4. Of those miles of roadway, approximately 50 miles (60%) are not planned for improvement. Map 6 and Map 7 displays the V/c categories for the entire CMS network.

Table 7 below summarizes current and future V/c data for those sections of the CMS network for which there are planned improvements. The centerline mileage of the improved segments is cross-classified vertically by the V/c range at which it presently operates and horizontally by the V/c range at which it is expected to operate. The final three columns summarize the V/c data, detailing by V/c range, the number of network centerline miles that will operate with an improved, or lower, V/c range, with an unchanged V/c range, or with a worse, or higher, V/c range. Table 8 summarizes the remainder of the existing network in the same manner.

Table 7: Summary of Centerline Mileage of Existing Roads Planned for Improvement

Base V/c Category	Future V/c Category 1	2	3	4	Total	Improved V/c Category	Unchanged V/c Category	Worse V/c Category
1	10.3	1.3	3.5	2.9	17.9	-	10.3	7.6
2	1.4	3.5	0.4	0.6	5.9	1.4	3.5	1.0
3	5.3	4.6	2.5	0.6	12.9	9.8	2.5	0.6
4	13.4	5.5	2.3	0.2	21.5	21.3	0.2	-
Totals	30.3	14.9	8.7	4.3	58.1	32.5	16.4	9.2
						56%	28%	16%

Legend:
- Improved V/c Category
- Unchanged V/c Category
- Worse V/c Category

Table 8: Summary of Centerline Mileage of Existing Roads Not Planned for Improvement

Base V/c Category	Future V/c Category 1	2	3	4	Total	Improved V/c Category	Unchanged V/c Category	Worse V/c Category
1	596.8	37.6	22.2	18.3	674.9	-	596.8	78.1
2	17.5	13.6	6.2	5.5	42.8	17.5	13.6	11.7
3	6.0	6.0	3.5	2.9	18.3	11.9	3.5	2.9
4	8.5	4.3	6.5	13.0	32.4	19.3	13.0	-
Totals	628.8	61.5	38.4	39.7	768.3	48.8	626.8	92.7
						6%	82%	12%

Legend:
- Improved V/c Category
- Unchanged V/c Category
- Worse V/c Category

Table 7 shows that approximately 56% of the existing centerline miles of roadway that are planned for improvement are expected to operate in an improved V/c range in 2010, 28% will operate in the same V/c range, and 16% will operate in a worse V/c range. Table 8 shows that by 2010 approximately 6% of the centerline mileage of the CMS network with no planned improvements will operate in an improved V/c range, 82% will operate in the same V/c range, and 12% will operate in a worse V/c range. For the network as a whole only 12%, or 101.9 miles, of the total centerline miles in the CMS network are expected to operate at a level worse than present conditions. The remaining 78%, or 724.5 miles, of the centerline miles will operate at current levels or better in the year 2010.

Summary of Proposed Roads in the CMS Network

The following tables and charts summarize only the new facilities planned to be added to the CMS network by 2010. Approximately 55 miles of new roads will be added to the CMS network by 2010. As already noted, these new facilities combined with the capacity improvements on the existing roads will result in altered travel patterns throughout the region.

The new roads were analyzed using the same methodology as the existing facilities. The analyses indicate that all of the proposed roads will operate in V/c category 1 in 2010, meaning all of the new roads will operate at acceptable levels. Table 9 summarizes the centerline miles of new roads using the base and future V/c categories.

Table 9: Summary of New Roads Planned for Construction

Base V/c Category	Future V/c Category 1	2	3	4	Total	Improved V/c Category	Worse V/c Category
1	53.6	-	0.4	1.1	55.1	-	1.5
Totals	53.6	-	0.4	1.1	55.1	-	1.5
						-	3%

Legend:
Improved V/c Category
Worse V/c Category

As shown in Table 9, the majority of the new facilities will continue to operate in V/c category 1 in the future. Only one and one-half miles of the new roadways is expected to operate at worse V/c category in 2010, indicating that in 2010 the new facilities will have substantial reserve capacity to accommodate future traffic growth beyond 2010.

No Build[1] Analysis

A no build analysis was preformed by using the predicted 2010 traffic volumes and the base year roadway capacities. This is not a true no build analysis in that predicted traffic volumes were greatly affected by the assumption that programmed roadway projects would be completed by 2010. A true no build analysis would have predicted 2010 traffic volumes based on 2010 socio-economic data and the base year roadway network. The results are summarized in Table 11 below.

Table 10: Summary of Centerline Mileage for No Build Analysis

Base V/c Category	No Build V/c Category 1	2	3	4	Total	Improved V/c Category	Unchanged V/c Category	Worse V/c Category
1	609.6	37.6	24.41	20.76	692.3	-	609.56	82.77
2	19.06	16.79	5.69	10.73	52.27	19.06	16.79	16.42
3	11.28	10.42	5.26	10.44	37.4	21.7	5.26	10.44
4	14.78	3.2	9.01	14.17	41.16	26.99	14.17	-
Totals	654.7	68.01	44.37	56.1	823.2	67.75	645.78	109.63
						8%	78%	13%

Legend:
Improved V/c Category
Unchanged V/c Category
Worse V/c Category

Analysis shows that if the planned widening projects for the City of Greensboro's roadway network were implemented, the existing roadway network would function below

[1] Not a true "No Build" analysis. V/c ratios are calculated using future year traffic volumes and base year roadway capacities.

the current level in the year 2010. Given that the Urban Loop is expected to divert a significant amount of traffic from the congested I-40/I-85 corridor and, to a lesser extent, other congested cross town routes, so much so as to improve the V/c conditions, the analysis predicting levels only slightly worse than current conditions in reality predicts that traffic will grow at a pace as to outstrip any gains that would be made from new construction alone.

Roadway Congestion Index

The roadway congestion index (RCI) is a useful measure to assess network efficiency and is most useful to compare transportation networks with varying characteristics from different metropolitan areas. The RCI is based on the ratio of principal arterial VMT per lane mile of principal arterial and the ratio of freeway VMT per lane mile of freeway. Additionally, the RCI is based solely on capacity and demand volumes. Travel speed is not factor in the RCI calculation. In simple terms, the RCI is the ratio of daily traffic volume to the overall capacity of the network. As with the v/c ratio, an RCI less than one indicates a functioning network, while an RCI greater than one indicates a network with impeded traffic conditions. The calculations that are involved in determining the RCI are included in **Appendix C**. In the current year, the RCI for the GUAMPO CMS network is approximately 1.49. This is due to the fact that for every lane mile of freeway there are 2,510 VMT as opposed to 422 VMT for every lane mile of principal arterial. The predicted RCI for the future network is 1.00, with 1,490 VMT for every lane mile of freeway and 477 VMT for every lane mile of principal arterial. Given these figures, it is expected that the future network for the City of Greensboro will more closely serve the needs of the driving populace than the current network does. Construction of the Greensboro Urban Loop and the NC 68/US 220 connector are expected to further decrease the RCI for the GUAMPO CMS network.

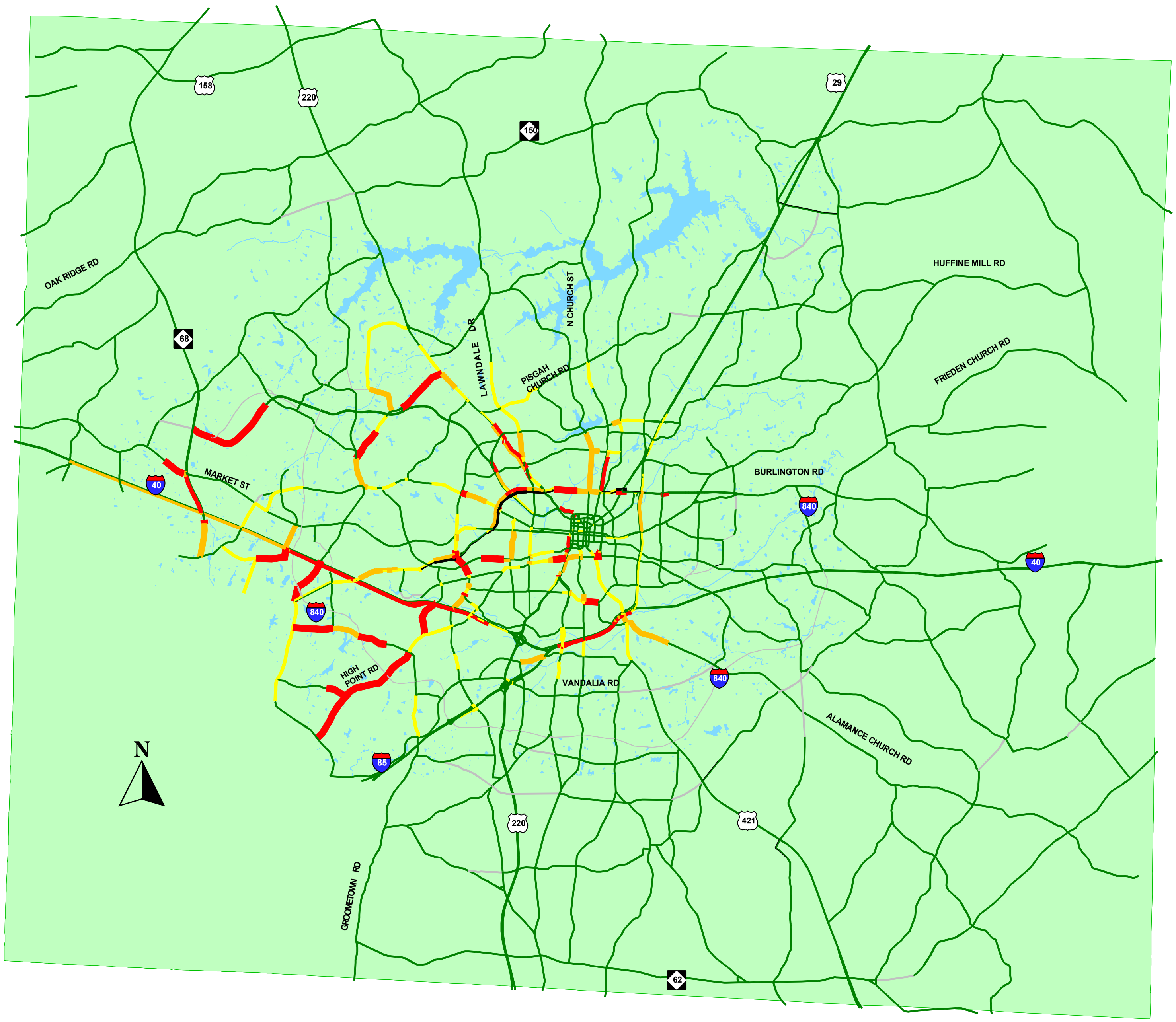


Figure 7

Base Year PM V/C Results

GUAMPO Area

Future Facilities
Base Year PM V/C
0.00 to 0.80
0.80 to 1.00
1.00 to 1.20
< 1.20

0 2 4 6
Miles

Prepared by:

MARTIN ALEXIOU BRYSON

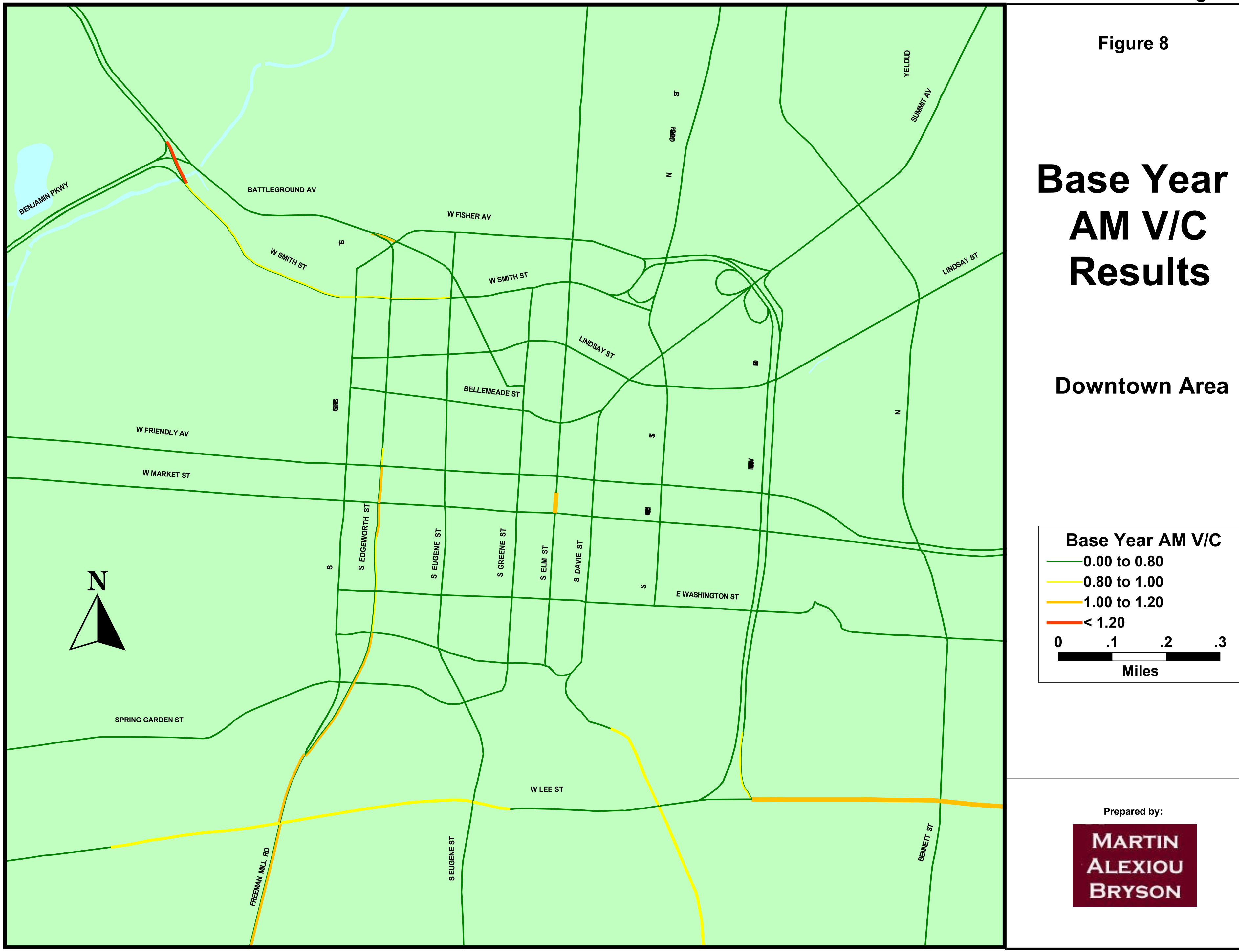


Figure 8

Base Year AM V/C Results

Downtown Area

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MARTIN ALEXIOU BRYSON

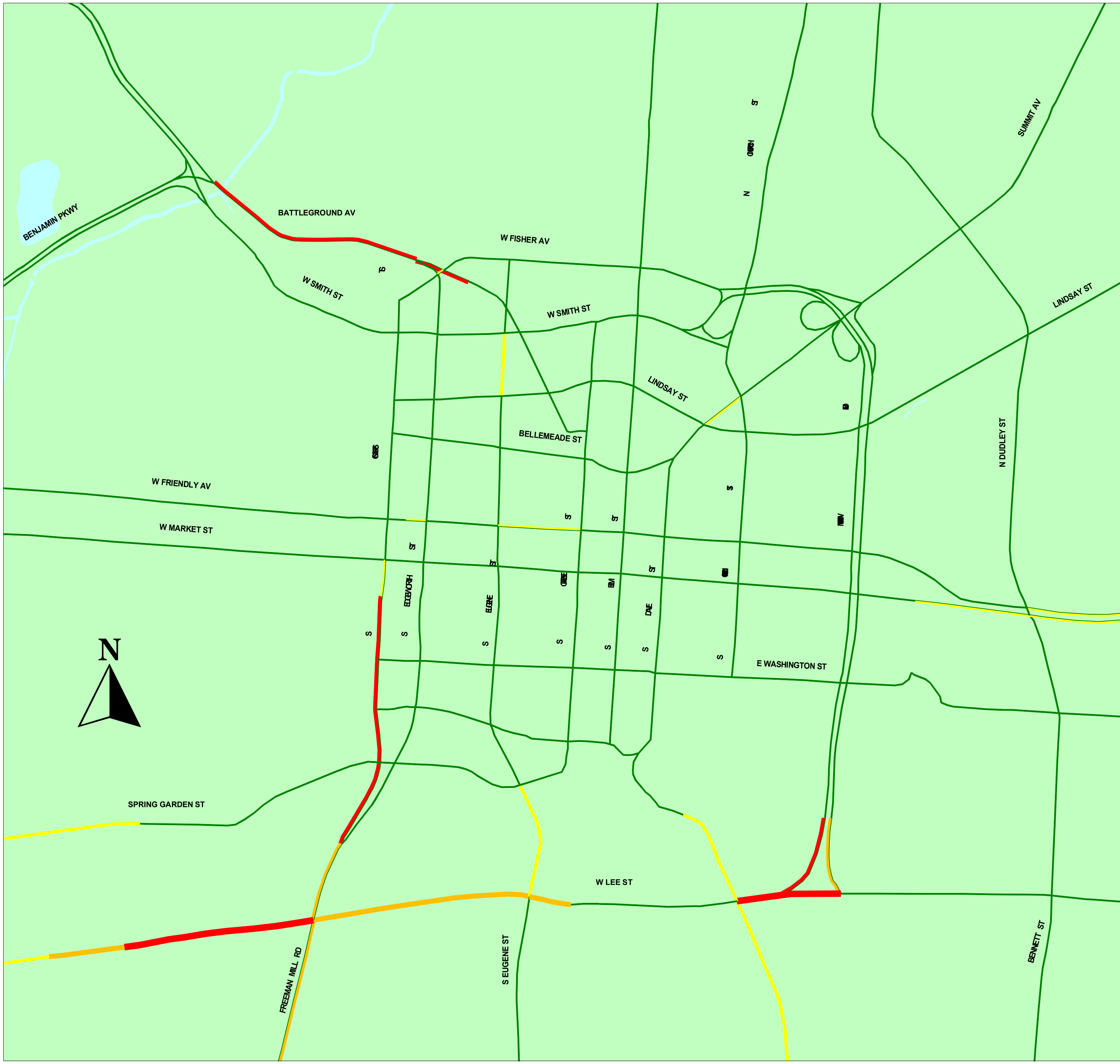


Figure 9

Base Year PM V/C Results

Downtown Area

Base Year PM V/C
- 0.00 to 0.80
- 0.80 to 1.00
- 1.00 to 1.20
- < 1.20

0 .1 .2 .3
Miles

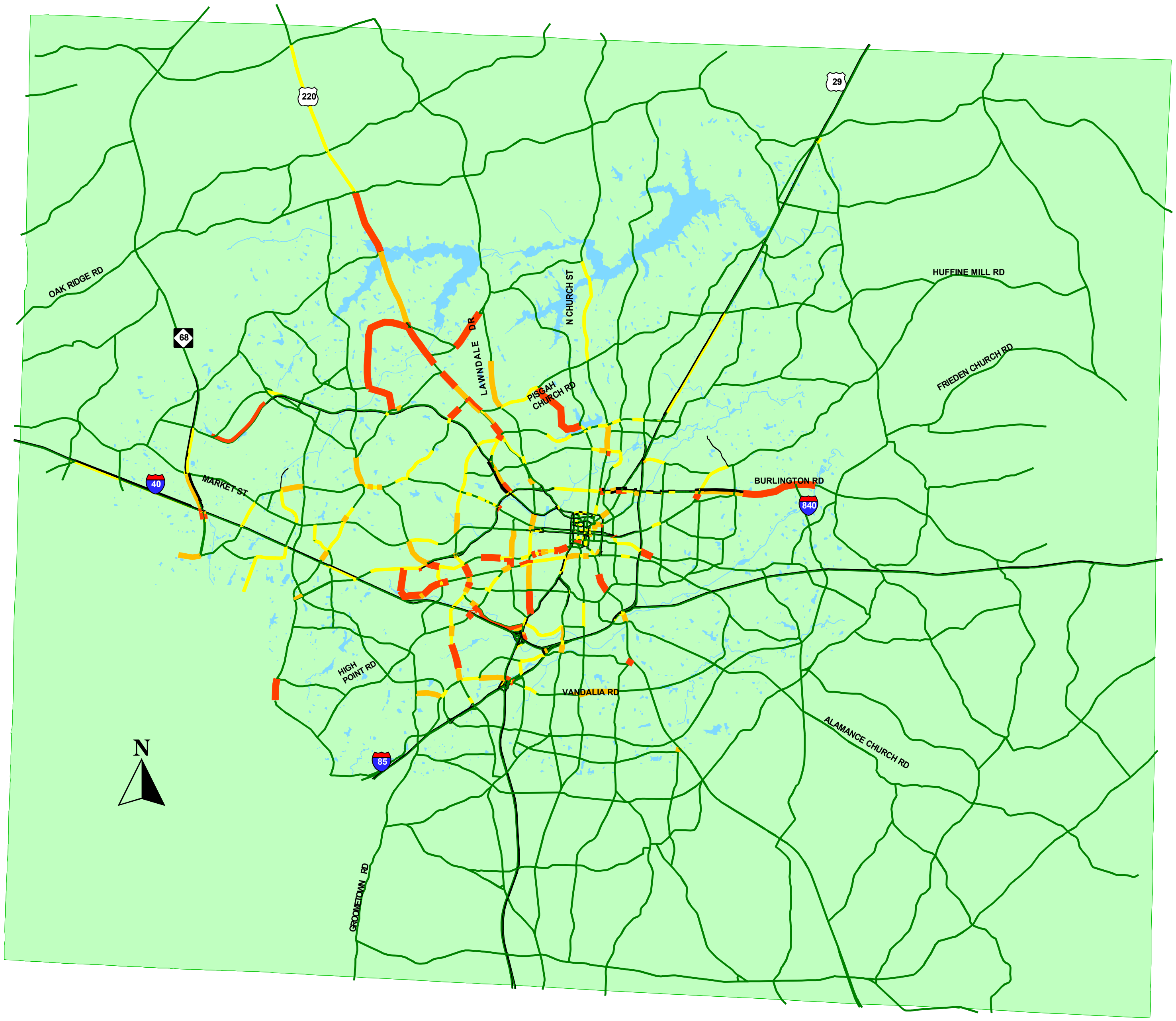
Prepared by:

MARTIN ALEXIOU BRYSON

Figure 10

Future Year AM V/C Results

GUAMPO Area



Future Year AM V/C
0.00 to 0.80
0.80 to 1.00
1.00 to 1.20
< 1.20
0 2 4 6
Miles

Prepared by:

MARTIN ALEXIOU BRYSON

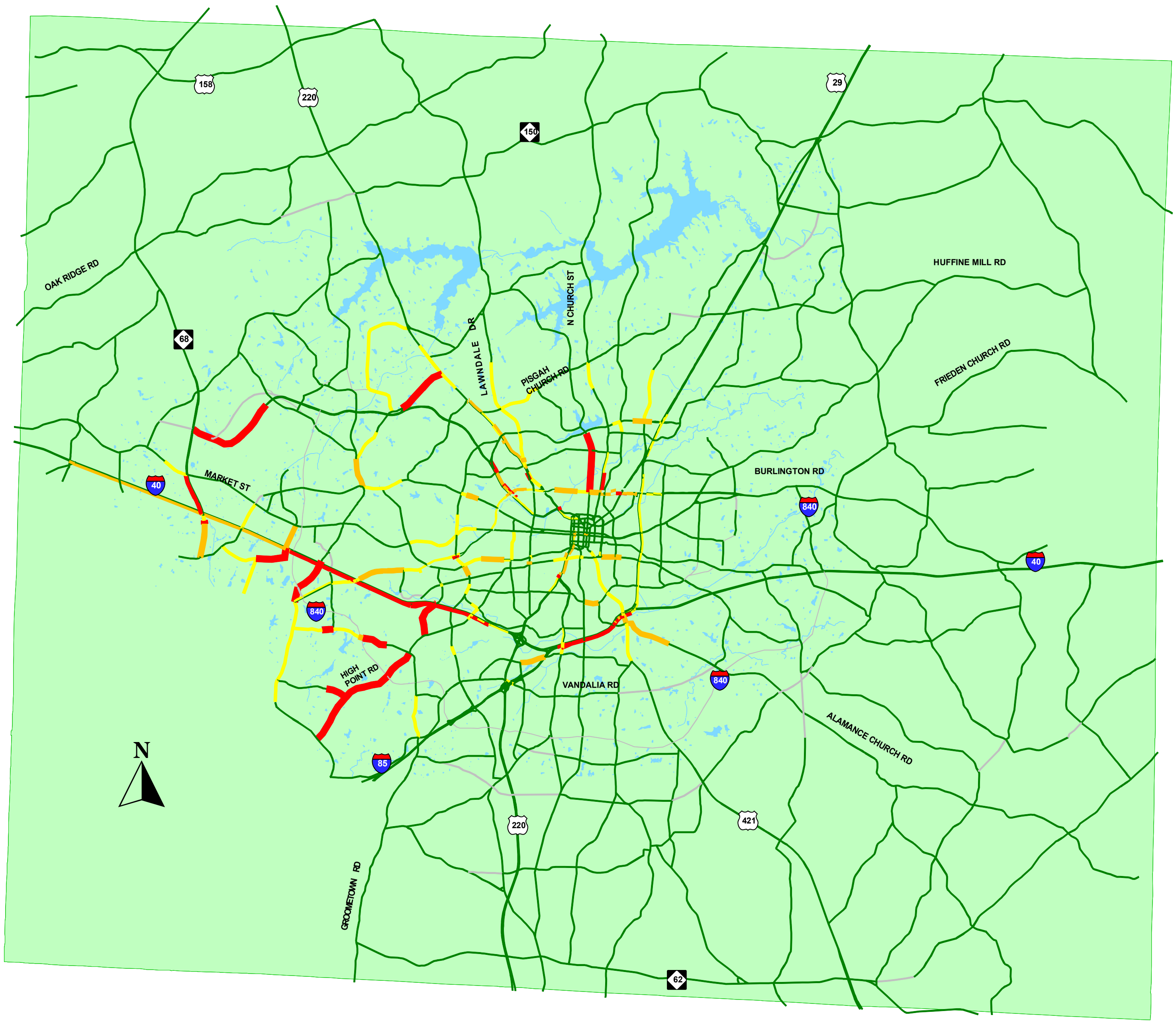


Figure 6

Base Year AM V/C Results

GUAMPO Area

Future Facilities
Base Year AM V/C
0.00 to 0.80
0.80 to 1.00
1.00 to 1.20
< 1.20

0 2 4 6
Miles

Prepared by:

MARTIN ALEXIOU BRYSON

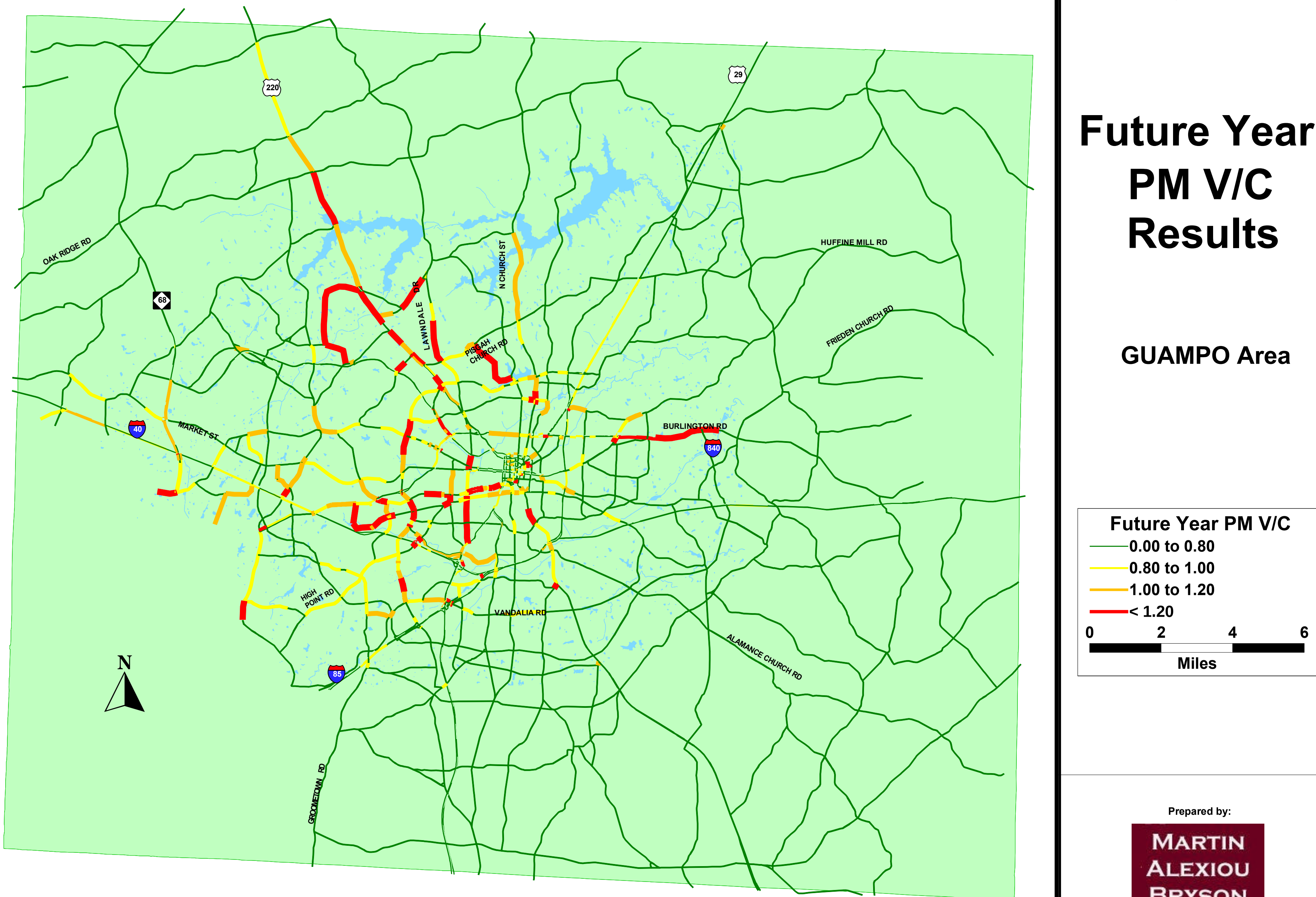


Figure 11

Future Year PM V/C Results

GUAMPO Area

Prepared by:

MARTIN ALEXIOU BRYSON

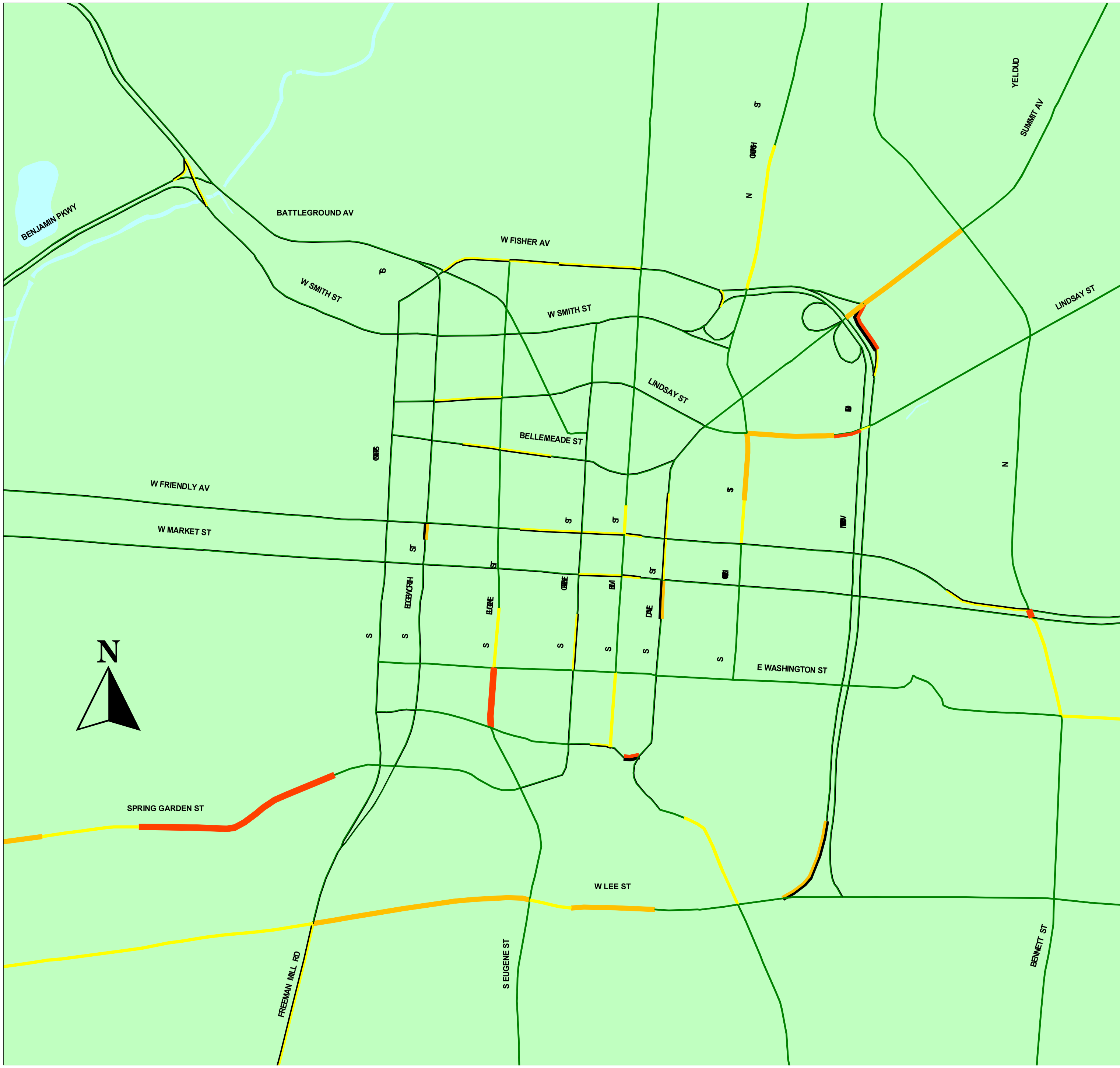


Figure 12

Future Year AM V/C Results

Downtown Area

Future Year AM V/C
- 0.00 to 0.80
- 0.80 to 1.00
- 1.00 to 1.20
- < 1.20

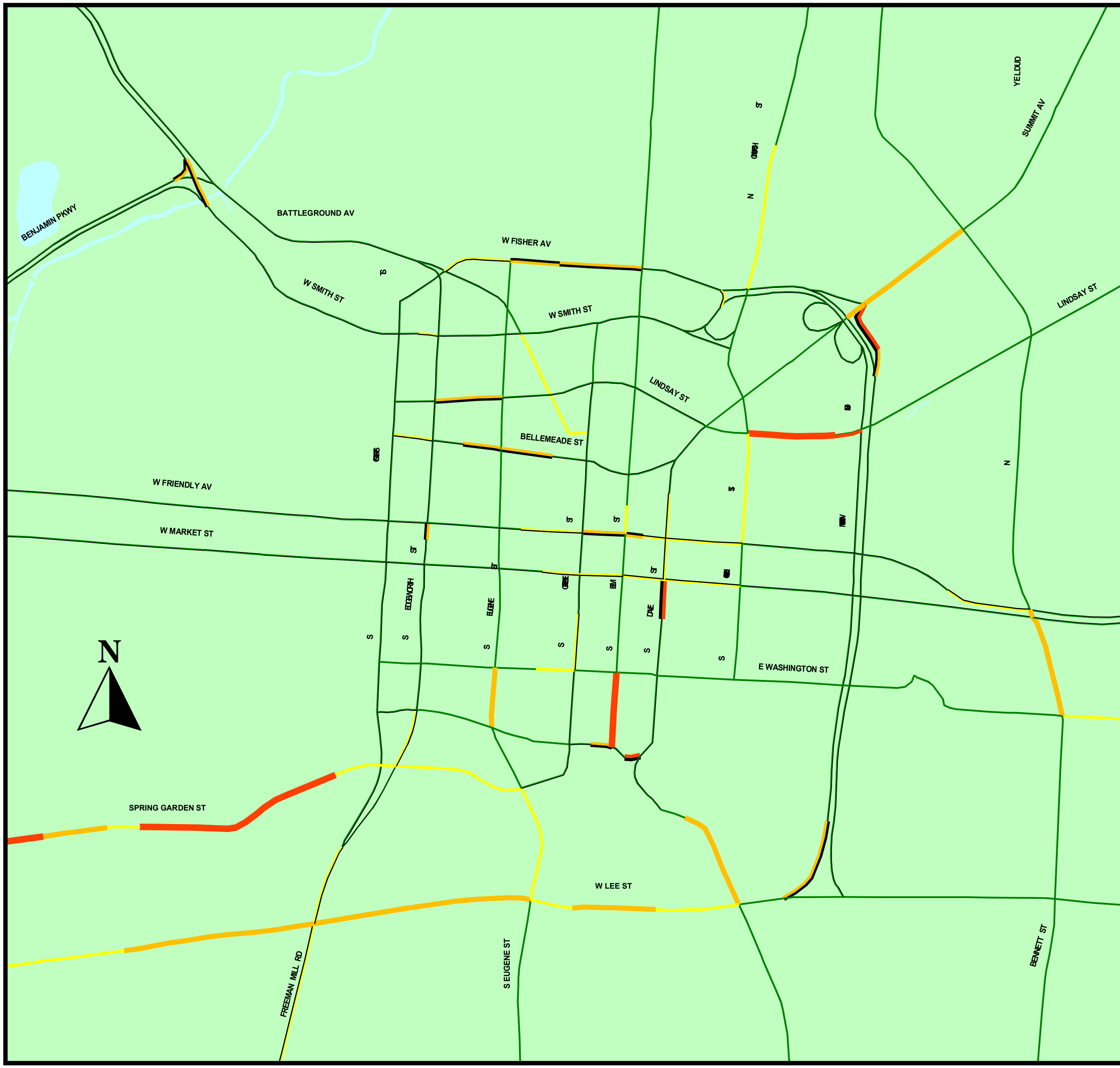
0 .1 .2 .3
Miles

Prepared by:
MARTIN ALEXIOU BRYSON

Figure 13

Future Year AM V/C Results

Downtown Area



Future Year PM V/C
- 0.00 to 0.80
- 0.80 to 1.00
- 1.00 to 1.20
- < 1.20

0 .1 .2 .3
Miles

Prepared by:

4.0 PEDESTRIANS AND BICYCLES

Provisions for pedestrians and bicycles are important elements in the transportation in the City of Greensboro. The following goal in the Transportation element of the Greensboro Comprehensive Plan indicates the importance of these modes:

> Develop and maintain a safe, efficient, and environmentally sound transportation system that provides convenient choices for accessing destinations throughout Greensboro and the Triad, including a range of well-integrated transit, pedestrian, and bicycle linkages.

From that, the City has adopted a number of policies aimed at reaching that goal.

4.1 GREENSBORO WALKABILITY POLICY

The Greensboro Walkability Policy was adopted with the goal of making the City more walkable. The policy identifies three actions to achieve that goal:

- Continue a City sidewalk program targeted to community and transportation system needs
- Respond to pedestrian safety, mobility, and access issues
- Adopt ordinances requiring the construction of sidewalks to meet the City's goals of pedestrian safety, mobility, and connectivity goals.

The Greensboro Walkability Policy has spawned other policy efforts to improve the environment for pedestrians and bicyclists in the City, including substantially strengthened sidewalk installation requirements.

4.2 PEDESTRIAN SAFETY PROGRAM

In response to the Greensboro Walkability Policy, the City has adopted a Pedestrian Safety Program. The pedestrian safety program has four specific goals:

- Promote pedestrian and bicycle travel.
- Authorize pedestrian and bicycle facility improvements
- Enhance safety and access of pedestrian and bicycle facilities
- Promote safe walking and bicycling

4.3 SIDEWALK PROGRAM

The sidewalk program consists of three primary elements:

- Identifying, prioritizing by need, and authorizing sidewalk projects;
- Participating in the development review process to require sidewalks under the Unified Development Ordinance; and
- Administering a petition process through which interested citizens may request a sidewalk.

All of these programs have resulted in an ambitious sidewalk construction program. Approximately 60 miles of sidewalk construction projects are in various stages of design, right-of-way, and construction.

4.4 URBAN TRAIL CONSTRUCTION

Understanding the need for a dedicated right of way for pedestrians and bicycles, Greensboro has implemented a long term planning program to provide urban trail connections throughout the City and County. These urban trails provide not only linear park space, but also dedicated paths with a higher degree of safety than standard sidewalks, for those persons who walk and cycle as a means of transportation, rather than as a recreational activity. One such project, the Battleground Rail Trail, will provide, in the short term, a route dedicated to cyclists and pedestrians parallel to Battleground Avenue, one of the busier streets in Greensboro. In the long term, this trail is expected to become part of a larger system of trails connecting Greensboro with High Point.

4.5 CITY INTERCONNECTIVITY POLICY

The goal of the Greensboro Interconnectivity Policy is to use the sidewalk and trail network to connect other modes of transportation. Specifically, the policy prioritizes those proposed sidewalk and trail projects that in addition to serving the needs of cyclist and pedestrians also provide a more direct and safer connection to transit services and local retail outlets. The desired result is a sidewalk and trail network that seamlessly connects with other modes of transportation.

4.6 ON-STREET BICYCLE ACCOMMODATIONS

The City of Greensboro Department of Transportation has incorporated wide outside shoulders to accommodate bicyclists on a range of City and NCDOT roadway construction projects. However, to date, a systematic plan for the provision of on-street cycling accommodations has not been conducted. It is recommended that the MPO and City prepare a bicycling accommodations study and Bicycle Plan to address this issue in the near future. Such a plan would complement the corridor management strategies recommended as part of the Congestion Management System.

5.0 TRANSIT

5.1 LOCAL TRANSIT

The Greensboro Transit Administration (GTA) owns and operates an extensive bus system that provides service throughout much of Greensboro. Connecting through the downtown hub, GTA provides services connecting residential areas of the City with industrial and retail centers. GTA also provides a Specialized Community Area Transportation (SCAT) that caters to disabled riders. SCAT provides a door-to-door service for those people who are medically unable to access ordinary transit vehicles.

5.2 REGIONAL TRANSIT

In addition to the services provided on the local level, the Piedmont Authority for Regional Transportation (PART) operates a regional bus system and a vanpool system. The regional bus system connects the downtown transit hubs of Greensboro, Winston-Salem, and High Point with a centrally located hub near the Piedmont Triad Airport. In addition to the connector service, PART will operate five park-and-ride lots to be constructed in the Triad region that are scheduled for construction in 2004.

PART also provides carpool/vanpool services to members of the PART community. A vanpool lease is available to commuters who live at least 10 miles from their workplace and agree to share their daily commute to and from work. A driver and at least eight commuters are required to start a new vanpool. All riders, except the driver, must agree to pay a monthly fare based on the number of riders and the daily round trip mileage. In this system, drivers are allowed free participation and limited use of the van for non-commuting purposes.

5.3 MOBILITY GREENSBORO

The Greensboro Transit Authority has recently completed a study examining options for improving transit conditions and ridership. This study has culminated in the preparation of the Mobility Greensboro Long Range Public Transportation Plan, which is currently in draft final form. The plan will be presented to the GTA Board at their next meeting, which is scheduled for Tuesday, May 25, 2004. Mobility Greensboro aims to set policy directives for transit in Greensboro at least through 2015, and in some instances through 2025. Under this study, methods are being explored to double transit ridership from 5,500 daily trips in 2002 to 11,000 daily trips by 2008. In addition, the study is examining ways to convert the current gasoline fueled bus fleet to a fleet using natural gas, as well as ways to increase daily trips to 25,000 by 2025.

6.0 MANAGEMENT STRATEGIES

6.1 MANAGEMENT STRATEGIES IN PLACE OR PROGRAMMED

The GUAMPO has already implemented and programmed a number of recommended management strategies. Many of the strategies currently in place are detailed on the GDOT website (http://www.ci.greensboro.nc.us/traffic/index.htm).

Expansion of Transit Operations

In an effort to double transit use from two million annual trips to four million trips the City of Greensboro has a major expansion to the transit system planned. The first stage includes local changes to the transit system, such as the inclusion of cross-town routes, shorter headways along routes, and a new downtown circulator service. In addition to these changes, new partnerships with local employers and universities will attempt to make transit a more viable option for typical single occupancy vehicle commuters.

In conjunction with local changes to the transit system the Piedmont Authority for Regional Transportation, PART, will continue to further implement a regional transit system. This system will connect the transit stations of Greensboro, Winston-Salem, and High Point through regional bus lines. In addition to the regional routes, five park and ride lots are programmed in the STIP that PART will operate and connect to regional and local transit routes.

Advance Traveler Information System and Variable Message Sings

The Advance Traveler Information System in Greensboro allows drivers to view roadway network conditions prior to making a trip and to alter travel plans based on that information. Traffic cameras are located along I-40 from US 29 to NC 68, one of the most highly congested corridors in Greensboro. Traffic cameras near the Greensboro Coliseum Complex show the effects of any special events that may be occurring. In conjunction with the traffic cameras, a website detailing construction, lane closures, and traffic alerts provides information about events that may negatively impact traffic conditions. Views from the traffic cameras are also shown on local City Cable Channel 13. The City of Greensboro was the first city in the state to provide traffic camera coverage on television.

Variable message signs (VMS) are currently in place in the region. Two VMS signs are located at the Greensboro Coliseum to provide traffic information for special events. VMS signs are also located along the major interstate corridors in the GUAMPO area and are programmed to be installed along the Urban Loop. Upon completion of the Southern Urban loop, variable message signs will be able to inform drivers of adverse conditions in the city and allow them to divert along an unimpeded corridor. In addition, VMS will be able to direct drivers to special events in a more efficient manner, allowing high-speed corridors to continue to operate efficiently.

Updated Signal System

The current signal system for the City of Greensboro controls 413 signals, of which 361 are coordinated across 34 individual zones. A fiber-optic based signal system is programmed in the latest TIP for construction and implementation in 2008. The proposed system will allow for signals to be retimed from a central location to actively adjust to atypical traffic conditions. Such active control will allow for the more efficient movement of traffic along the roadway network.

Transportation Demand Management Strategies
Other than expanded transit systems and park and ride lots, the GUAMPO has not implemented any other transportation demand management strategies (TDM) to reduce the number of single occupant vehicles on the roads. Employer based TDM strategies such as ridesharing and ride-matching programs could at minimum address traffic congestion local to the employer sites. The success of these programs depends on the cost of the programs to the user and what incentives can be leveraged to attract and maintain a high number of users.

Traffic Safety and Emergency Roadside Assistance
While crash data is not specifically incorporated into the analysis of existing or projected conditions, safety is always an important consideration in transportation planning. Biennially the City of Greensboro undertakes a comprehensive study of safety within the city limits. The goal of this study is to identify those locations and corridors that experience unusual accident activity. Hazardous locations are identified using a Severity Index, an Equivalent Property Damage Only Rate, a Fatal Crash Analysis, a Corridor Improvement Program, and requests for service from the public. From this analysis the intersections deemed to be the least safe are studied, and spot safety improvements are identified. These recommendations serve as the basis for a list of Safety Program Improvements.

NCDOT provides emergency roadside assistance through the Incident Management Assistance Patrol (IMAP) on all the interstates (I-40 and I-85) in the region as well as US Route 29. The task of the program is to provide motorists with the assistance they need in order to clear incidents as quickly as possible so that they to not become accidents or cause significant traffic delays. The current IMAP coverage for the region is shown in Figure 14.

Ride Sharing/Car Pooling Programs
PART currently offers two programs aimed at decreasing single occupant vehicles. The RSVP program provides a driver and a minimum of eight passengers the use of a van for work commutes. As part of this program the driver must live 10 miles away from their work place, collect the monthly fees from the passengers, and complete a daily mileage log. In return the driver is allowed to ride the van at no cost and use the van for limited personal use. In addition to the RSVP program PART offers a service matching people who have a desire to carpool with others who have similar destinations and work schedules.

Access Management
In 2004 the City of Greensboro will complete an update to the City Driveway Manual. The local update is intended to dovetail with the recently completed update to the NCODT Driveway Manual. These revisions aim to maximize current and future roadway capacity by maintaining free flow characteristics to the highest extent possible. Additionally the City and State have engaged in the selective provision of access management measures such as installing concrete median islands on five lane sections with a history of traffic and/or congestion issues due to uncontrolled turns. As access management helps to maximize the investment in to the road network, it is recommended that the City of Greensboro continue to make every effort to develop an appropriate access management policy.

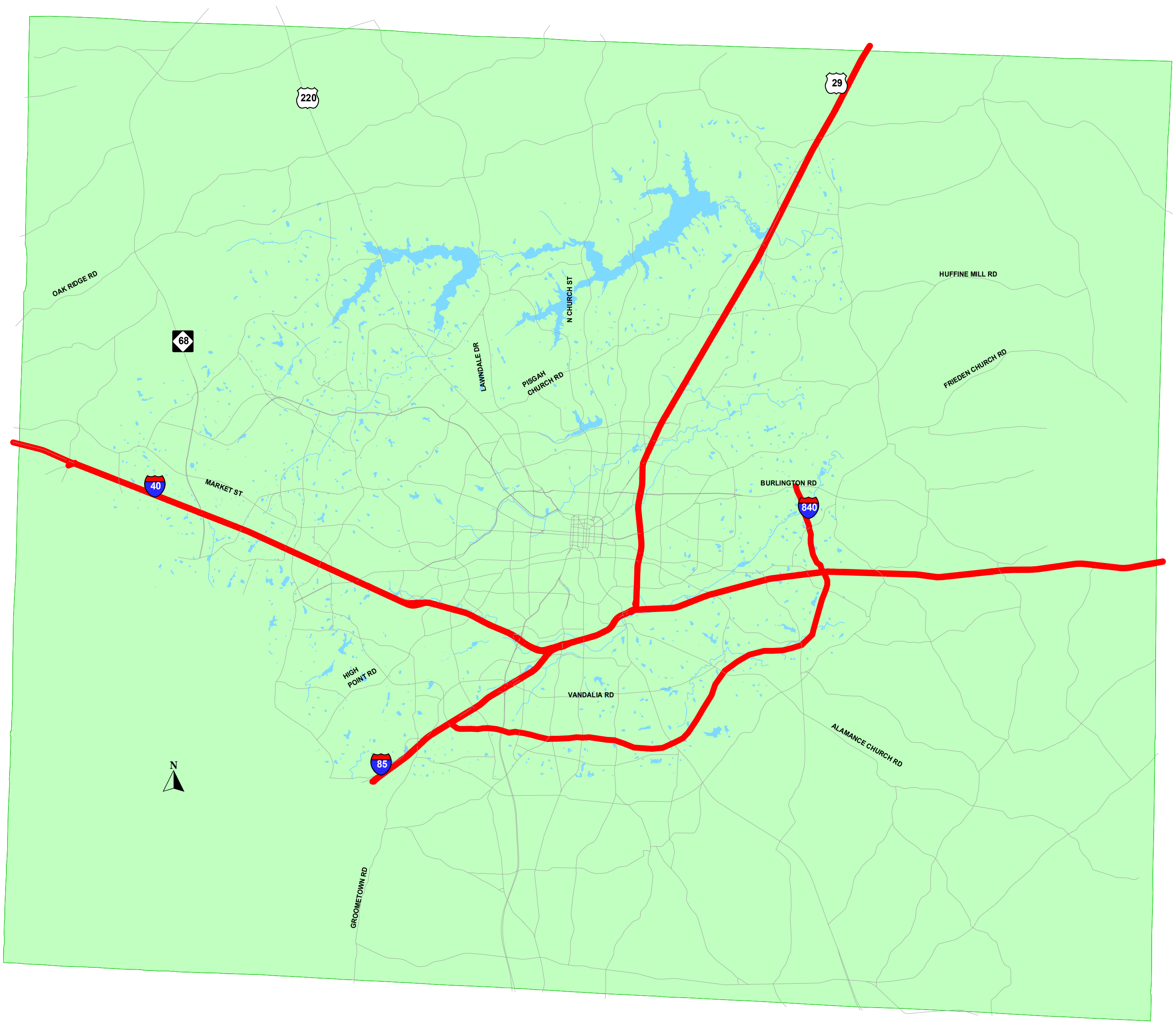


Figure 14

NCDOT IMAP* Coverage

GUAMPO Area

IMAP Coverage

0 2 4 6

Miles

* - Incident Management Assistance Patrol

Prepared by:

MARTIN ALEXIOU BRYSON

Corridor Improvement Program

GDOT's Corridor Improvement Program provides for evaluating specific corridors for needed improvements, including updated signal timing plans. This program serves to develop more corridor specific operational strategies, as opposed to widening and new construction alternatives.

Value Pricing

Value pricing is a concept growing in consideration nationwide. Sometimes called, congestion pricing or peak period pricing, it calls for drivers to pay tolls during peak periods of traffic congestion. Tolls vary by the time of day and level of congestion. The intent is to encourage drivers to better manage their driving habits by driving during typical non-peak times or to use alternate routes or modes. The tolls that are paid can act as an indicator of congestion and as a capital generator for future roadway improvements. A value pricing study is underway for I-40 in the Piedmont Region to consider the appropriateness of value pricing as a strategy to address congestion in the corridor.

6.2 STRATEGIES RECOMMENDED FOR FURTHER STUDY AND IMPLEMENTATION

The goal of management strategies is to manage the travel demand placed upon the transportation system without adding capacity to the transportation system. While altering travel behavior and travel patterns to suit the transportation system currently in place is the most ideal way to manage traffic and congestion, the steps necessary to alter travel behavior and travel patterns system-wide are not always feasible. Current management strategies therefore, focus on utilizing the capacity of the transportation system more effectively, quick response to roadside incidents, and reducing the number of vehicles on the roadways. All of these recommended strategies focus on both recurring and non-recurring traffic congestion.

Signal System Upgrades

One of the most common strategies applied is an upgrade of antiquated pre-timed signal systems to traffic responsive signal systems. This strategy, while effective, often is the least visible to the traveling public. A control system that provides the most efficient operation possible is a necessity. Although pre-timed signal systems do have the capability to provide signal operations that vary by the time of day, all of these systems are limited in that the timing does not dynamically change as the traffic demand fluctuates. In other words, unless the ideal traffic conditions for which the pre-timed signals are programmed actually occur, the efficiency of the system is not realized.

New technologies have lead to the development of traffic adaptive traffic control systems. Two examples of such systems are the Sydney Coordinate Adaptive Traffic System (SCATS) and the Split Cycle Offset Optimization Technique (SCOOT) system. Although both of these systems were developed in other countries, both have been successfully implemented in cities in the United States. The premise behind both systems is to dynamically adjust traffic signal timings in response to current traffic demands. This is accomplished through a system of traffic sensors along the corridors.

A feasibility study has already been completed for a signal system upgrade within the City of Greensboro. That study concluded that the pre-timed signals in the core downtown area will remain in operation.

Advance Traveler Information Systems

New technologies have also been utilized to provide better, timelier information to the traveling public. Providing advance travel information allows drivers to adapt their travel patterns and travel habits to more efficiently utilize system capacity. Traffic reports have long been included on television and radio news broadcasts in the larger metropolitan areas. Traffic information is shown in the Greensboro area on local cable channel 13. Now, through opportunities offered by the internet, traffic information has become even more accessible and the traffic information is not limited to only static reports. The technologies offered by the internet provides the opportunity to provide updated reports on traffic conditions. The types of data available through the internet reports include travel video displays of the roadway conditions as captured by roadside cameras.

In addition to the ability to provide reports on recent traffic conditions, the internet also provides the opportunity to display static information on traffic conditions expected to occur. For example, information can be provided on planned construction and special events that will affect travel conditions. The information might include location and duration of construction activities or alternative routes for special events.

Variable Message Signs

Roadside variable message signs, when used in coordination with other components of an intelligent transportation system, can be extremely beneficial to the traveling public. Variable message signs can be used to provide traffic information to motorists already out on the roadways. The messages provided on the signs can offer information of either recurring or non-recurring traffic congestion. The intent is to provide motorist with timely, accurate information to allow them to travel alternative routes if possible.

Emergency Roadside Assistance

While emergency roadside assistance is perhaps one of the least technologically intensive strategies currently being implemented across the country, it is often the most obvious to the traveling public. Because it is one of the most obvious strategies, a successful emergency roadside assistance program offers a great opportunity for recognition in the public eye, which is vital when implementing such programs. Traffic congestion due to non-recurring events, such as traffic accidents and other roadside incidents (out of fuel, flat tire, etc.), can account for a substantial portion of travel delay. While opinions vary on the impact of roadside incidents, it is widely accepted that quick response to those events is critical to both motorists' delay and safety. Emergency roadside assistance programs are typically provided only on interstate and expressway facilities.

Transportation Demand Management

Transportation demand management (TDM) focuses on reducing the number of vehicles on the roadways primarily through programs that promoting ridesharing in the workplace. TDM programs can be very useful in solving localized traffic problems. A few examples of TDM programs are ridesharing programs and subsidized transit fare programs. Both of these programs can not only reduce the demand for employee parking, but can also reduce vehicle miles traveled. The success of these programs depends on a number of factors; perception of the transit system, comparable travel times, accompanying guaranteed ride-home programs, and costs to the employee. Poor public perception of the local transit system, long transit trip time, the inability of employees to travel home in case of emergency, and high employee costs can doom these types of programs to fail. Telecommuting is another TDM strategy aimed at reducing vehicle demand on the transportation system. This strategy has come under some scrutiny due to concerns of worker accountability. Another TDM strategy to consider is flexible work schedules. While not reducing the overall vehicle demand on the transportation system, flexible work schedules can effectively spread the typical peak traffic demand over several periods reducing the vehicle trips during the normal peak hours.

Regional Freight Specific Planning

A number of transportation and private projects are expected to have a significant effect on the freight traffic throughout the GUAMPO and the Triad region. Interstate improvements and the FedEx hub at the Piedmont Triad International Airport will increase dramatically the number of tractor-trailer and air-freight trips into the region. Planned improvements to the rail infrastructure will provide additional capacity for more rail-freight trips in to the Triad region. To prepare for and efficiently manage the future freight traffic it is recommended that the region develop and adopt an Intermodal Management System (IMS) to meet the growing needs of freight transportation planning in the region. The benefits of an IMS include increased emphasis on freight planning, identification of modal conflicts, identification of transportation improvement specifically intended to improve freight traffic in the region, and involvement of the local and state freight industries in the regional planning process.

6.3 EFFECTS OF RECOMMENDED MANAGEMENT STRATEGIES

The intent of all of these management systems is to provide the opportunity to more effectively utilize the regional surface transportation system for all users without the expense of adding system capacity through new road construction or widening of existing roads. While some strategies are aimed at managing the supply side of the transportation system, such as upgraded signal systems, advance traveler information system, and variable message signs, other strategies are aimed at managing the demand on the system. Transportation demand management strategies can reduce the demand placed on the transportation system if effectively implemented. The combined effect of these strategies is increased vehicle occupancy, reduced traffic demand in the typical peak hours, and reduced travel delay.

6.4 STRAGETY IMPLEMENTATION

The nature of the congestion will dictate which management strategy to implement. The intended impact of the strategies varies from localized areas to regional. Strategies such as ATIS are intended to have a regional effect. Others such as coordinated signal systems may only be useful for corridors. While others, like spot safety project programs or employer specific TDM programs, are only aimed at reducing congestion in small areas or intersections. Non-recurring congestion, such as delays due to traffic accidents or special events can be addressed by emergency roadside assistance and a system of variable message signs. There is no silver bullet that will solve all congestion problems, but all management strategies will be considered before identifying a new road construction project or a road-widening project to address congestion.

7.0 SYSTEM MONITORING

The GUAMPO transportation system is currently monitored jointly by the Greensboro Department of Transportation and the North Carolina Department of Transportation. Through the joint efforts of these agencies vehicle crash data, average annual daily traffic data, and peak hour traffic data is collected and maintained databases for historical tracking. The Greensboro Department of Transportation currently collects the peak hour traffic data at signalized intersections. The NCDOT collects average annual daily traffic counts at locations throughout the region and maintains a database of all vehicle collisions in the region. The data collected by NCDOT is accessible and provided to GDOT upon request.

Vehicle travel speeds and travel time are the ideal measures of the efficiency of a transportation system. Current data collection programs of GDOT and NCDOT do not include the collection of travel speeds or travel time in the urban area. While the traffic data collection programs are also vital to system monitoring for planning purposes, travel times will give a more complete picture and clearly identify the inefficiencies in the transportation system.

The methods and level of technology used to collect travel speed and travel time data by the desired use of the information. Some jurisdictions have developed extensive systems for the collection of travel time data utilizing global positioning system (GPS) equipment, while others perform simple curbside speed studies using a speed (radar) gun. The more robust systems are capable of collecting travel speed along roadways using GPS equipment mounted inside vehicles traveling the roadways during the peak hour traffic conditions. The data is then exported from the GPS unit into a format that is compatible with geographic information system (GIS) programs such ESRI ArcGIS. Some jurisdictions have taken the use of travel time data even further. Custom programs have been written to manipulate the data to generate travel time contours for traveling either towards or away from any point on the roadway network. Typical applications include emergency planning and economic development planning.

As in any endeavor, the cost travel of time data collection is relative to the level of technology used and the required end result. Methods are available to collect data with the use of GPS technology at much less expense, but the tradeoff is the usefulness of the data.

8.0 RELATIONSHIP TO LRTP AND PUBLIC INVOLVEMENT

8.1 IDENTIFICATION

As per federal guidelines, an update to the CMS is required every two years. This ensures that transportation planners and local officials are constantly up to date on current conditions and expected near term conditions. Dutiful updates of the CMS should provide the necessary identification of problematic corridors. It is not expected that specific projects will be identified by the CMS. However, GUAMPO is a 1-hour maintenance area and an EAC participant. The CMS is needed to meet the requirements that come with those designations. It will be necessary to develop a new CMS within close proximity to an LRTP update and document the areas of congestion as defined by the CMS prior to adding any projects that increase roadway capacity in to a new LRTP. Failure to analyze projects in the CMS prior to their addition to the LRTP would fail to meet the requirements set forth by FHWA and other federal agencies.

8.2 CMS AND THE LONG RANGE TRANSPORTATION PLANNING PROCESS

The LRTP identifies transportation projects and priorities up to a twenty-five year planning horizon. The LRTP allows local planners to allocate resources in accordance with the long-term mobility goals. The CMS should become another tool in the long range planning process by detailing the cumulative effects caused by the completion of new projects between iterations of the LRTP. In the future, this knowledge will allow local transportation planners to more accurately identify future needs during the process of updating the LRTP. As the CMS becomes a part of the LRTP process, it will by default be open to public involvement.

9.0 FINDINGS AND RECOMMENDATIONS

An effective congestion management system can serve many varied functions to a regional transportation planning organization. To the technician, the CMS can be a comprehensive collection of all regional traffic and roadway data. To the decision-makers, the CMS can be an invaluable tool in setting priorities for both the short term and long term planning horizons. This initial CMS for the Greensboro Urban Area Metropolitan Planning Organization will set the foundation for future enhancements to the transportation planning process for the region.

The roads selected for study in the CMS are those that are considered regionally significant. The network studied includes 826 centerline miles of existing roads and 55 centerline miles of new roads programmed to be built by 2010. Based on those centerline miles, the existing roads included in the network constitute approximately 2,080 lane-miles of vehicle carrying capacity while the network for 2010 presents a total of approximately 2,400 lane-miles of vehicle carrying capacity.

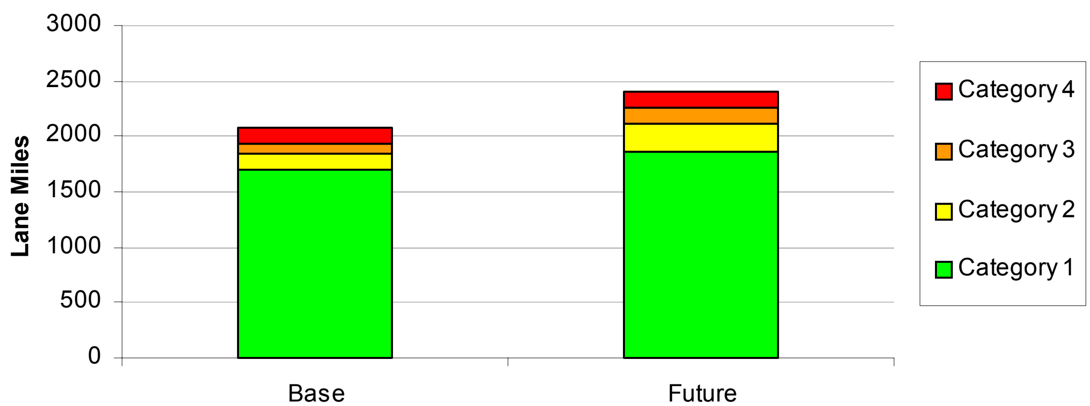
Traffic data was gathered from both the City of Greensboro and the North Carolina Department of Transportation for study in the CMS. The City of Greensboro provided peak hour traffic counts at all of the signalized intersections in the urbanized area as well as daily traffic volumes at locations throughout the region. Average annual daily traffic was gathered from NCDOT to supplement the data provided by the City of Greensboro.

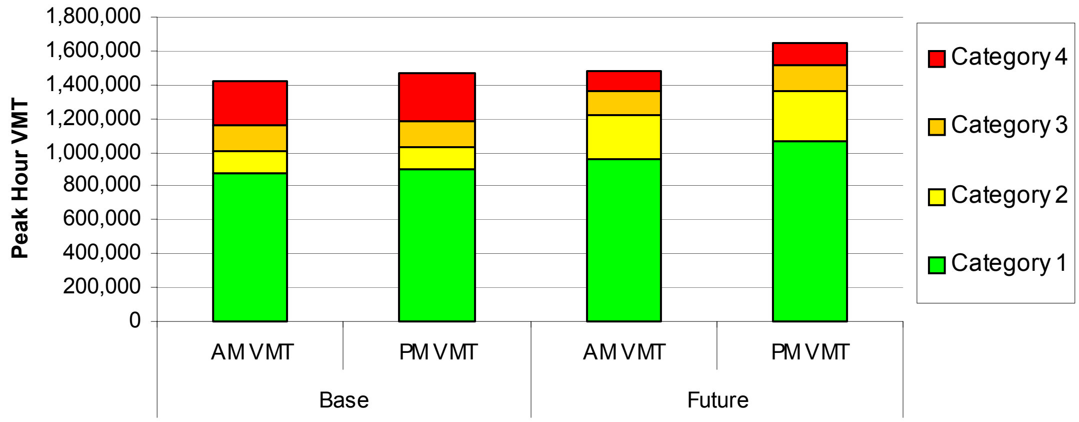
Analyses Results

The analyses indicate that the majority of the roadways in the network operate at acceptable levels and that the majority of the roadways in the region will continue to operate at acceptable levels in 2010. The table and chart below summarize the analysis results by existing and future V/c category using lane-miles as the measure.

Total Lane Miles and Vehicle Miles Traveled

	Lane Miles	AM VMT	PM VMT
Base	2076.6	1,426,755	1,467,157
Future	2405.0	1,481,040	1,645,720
Change	328.4	54,285	178,563





Management Systems
The City of Greensboro has been very proactive in implementing management strategies aimed at increasing the efficiency of the transportation system without adding additional capacity to the roadways. The City currently has already implemented the following management strategies:

- Expansion of Transit Operations – The City has planned a major expansion of the local transit system to double the ridership annually from two million trips to four million trips. In addition, the Piedmont Authority for Regional Transportation (PART) has planned to implement a regional transit system that will connect transit stations in Greensboro, Winston-Salem, and High Point. Five park and ride lots are also programmed as part of the regional transit system.
- Advance Traveler Information System (ATIS) and Variable Message Signs (VMS) – Views from roadside traffic camera, information on road closures, and other essential traffic data is provided on the City's website. Variable message signs are already in place along the existing major interstate corridors in the region. The VMS system will be expanded to the new Urban Loop also.
- Updated Signal System – The City has programmed a citywide signal system upgrade to provide more efficient operation of the traffic signals in the region. The new system will be monitored from a new central management center.

Other than expanded transit systems and park and ride lots, the GUAMPO has not implemented any other transportation demand management strategies (TDM) to reduce the number of single occupant vehicles on the roads. Employer based TDM strategies such as ridesharing and ride-matching programs could at minimum address traffic congestion local to the employer sites. The success of these programs depends on the cost of the programs to the user and what incentives can be leveraged to attract and maintain a high number of users.

Pedestrians and Bicyclists
In addition to improving the efficiency of the roadways in the region, the City of Greensboro has also made mobility and access for pedestrians and bicyclists a regional priority as well. Statements in the Greensboro Comprehensive Plan, the adoption of the Greensboro Walkability Policy, the Pedestrian Safety Program, and the Sidewalk Program are all evidence the commitment City has made for pedestrians and bicyclists. The goal of these policies is to improve safety and awareness of pedestrian and bicycle travel through the provision of safe and accessible facilities throughout the City.

System Monitoring
The GUAMPO transportation system is currently monitored jointly by the Greensboro Department of Transportation and the North Carolina Department of Transportation. Through the joint efforts of these agencies vehicle crash data, average annual daily traffic data, and peak hour traffic data is collected and maintained databases for historical tracking. The Greensboro Department of Transportation currently collects the peak hour traffic data at signalized intersections. The NCDOT collects average annual daily traffic counts at locations throughout the region and maintains a database of all vehicle collisions in the region. The data collected by NCDOT is accessible and provided to GDOT upon request.

Vehicle travel speed and travel time are the most ideal measures of the efficiency of a transportation system. Current data collection programs of GDOT and NCDOT do not include the collection of travel speeds in the urban area. While the traffic data collection programs are also vital to system monitoring for planning purposes, travel speeds will give a more complete picture and clearly identify the inefficiencies in the transportation system.

Recommendations
The GUAMPO has been very proactive in implementing policies and programs to more efficiently manage the transportation system in the region, however there are areas where improvements can be made.

- Expand the system monitoring efforts to include the collection of peak hour vehicle travel speeds. Peak hour travel speeds are the true indicator of system efficiency.
- Develop a transportation demand management strategy (TDM) focusing on the larger employers in the region. Successful transportation demand management programs will reduce local parking demand and traffic congestion. TDM programs could focus on ridesharing and the use of transit.
- Accelerate funding to implement the regional signal system upgrade and construction of the traffic management center.
- Accelerate funding to implement improvements to the local and regional transit system including the construction of park and ride lots.
- Update the CMS as the initial stage to every LRTP update. Data should be collected to satisfy the schedule requirements of the updates to the CMS.
- Continue to collect roadway geometric data for new roads and expand traffic volume data collection to cover more of the CMS network. The coverage of data collection should be expanded in concert with the expansion of regional transportation planning priorities.
- Collect vehicle travel time data on roadways in the CMS network. It is recommended that the MPO first determine the level of output desired from a travel time data collection system. The next step is to then decide the level of technology required to meet those needs. The level of technology required will dictate the financial commitment necessary. Some of the more robust systems currently in application in other areas utilize GPS technologies, while others require much less advanced data collection methods but the tradeoff will be the usefulness of the collected travel time data.
- Coordinate CMS development with the congestion and safety related intersection improvement programs of the City of Greensboro and NCDOT.

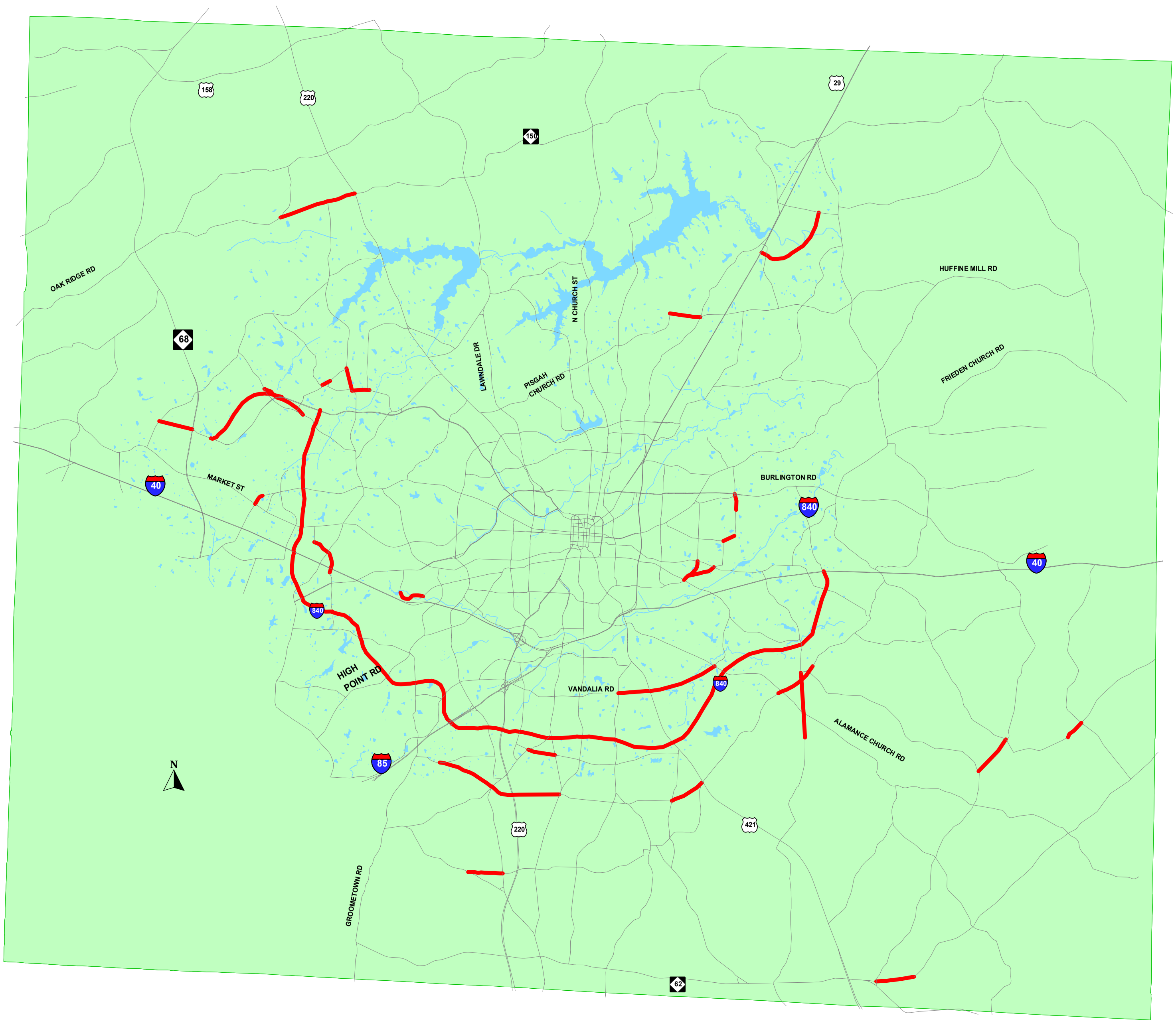
In addition to implementing new efforts, it also recommended that current efforts continue:

- Encourage NCDOT to continue the IMAP motorist assistance program on the existing interstates in the region and expand the system onto the new interstates as they open to traffic.
- Continue the joint efforts with NCDOT to monitor the regional transportation system.
- Continue expanding and enhancing the management systems that are already in place.

APPENDICES

APPENDIX A

PROPOSED ROADWAYS



Appendix A

Proposed Roadways

GUAMPO Area

Future Facilities

0 2 4 6

Miles

Prepared by:

MARTIN ALEXIOU BRYSON

APPENDIX B

CAPACITY CALCULATION VARIABLES AND ASSUMPTIONS

3. ROADWAY CAPACITY

When estimating traffic demands on uncongested roadways, the most important network variable is link travel time, usually calculated from the speed and length of individual roadway links. In dealing with congested conditions, however, an accurate determination of capacity becomes critical, since the relationship between traffic volume (demand) and roadway capacity (supply) determines travel speed (and, therefore, traversal time) for each roadway link. Errors in estimating link capacities can affect route selection, level-of-service and deficiency analysis, emission estimates, and a range of other important applications, either directly obtained or derived from model runs.

1. DEFINITION OF CAPACITY

A fundamental issue in network-based travel demand modeling is the definition of roadway link capacity. Historically, roadway capacity in travel demand models has often been defined for LOS C or D, often referred to as the "design capacity." The standard BPR curves assume this definition of capacity. In some cases, capacity has been defined as the volume at which free-flow speed drops by some percentage (typically 15% - 50%). Recently, the state-of-the-practice has moved towards using "ultimate" capacity, or the boundary between LOS E and LOS F.

There are several sound justifications for using ultimate, rather than design capacity [adapted from ref. 1-4]:

- Ultimate capacity is a unique quantity that can be determined objectively and mathematically; design capacity is much more subjective and qualitative, and can be influenced by changes in context, policy, and expectation.
- Ultimate capacity is always easier to calculate than design capacity, and can be computed more accurately and reliably. Due to increased congestion and lower travel speeds, capacity at LOS "E" is no longer sensitive to many of the variables needed to compute capacity at LOS "A" through "D," greatly simplifying the computations and reducing data requirements. For example, geometric design parameters (such as lane width, lateral clearance, no-passing zones, medians, and access density) can no longer have a significant impact on traffic flow at LOS "E," and have little relevance in determining capacity. A 12-foot travel lane offers no better performance than a 10-foot lane in stop-and-go traffic.
- Ultimate capacity can be consistently defined for all facility types; design capacity varies depending on the type of facility. Differences are especially significant between uninterrupted and interrupted flow facilities, and for two-lane highways.
- Ultimate capacity is more directly related to traffic counts; determination of design capacity can require estimates of density, percent time delayed, speed, percent time-spent-following, stopped delay, control delay, etc.
- Ultimate capacity corresponds (at least conceptually) with the maximum volume that should be assigned to a given link; design capacity lacks this simple, fundamental relationship, complicating the calibration and forecasting processes.

- Ultimate capacity provides a more solid and simple basis for developing the volume/delay functions needed to estimate the effects of congestion on travel speeds, since ultimate capacity occurs at a min/max point on flow-density and speed-flow curves. Design capacity is located on an arbitrary point along a given curve, and a very complex formula would be needed to accurately account for a range of possible design capacities on each facility-type curve. Furthermore, this formula would still need to represent the relationship between design and ultimate capacities.

2. HCM 2000

The fourth edition of the *Highway Capacity Manual (HCM 2000)* "Is intended to provide a systematic and consistent basis for assessing the capacity and level of service for elements of the surface transportation system and also for systems that involve a series or a combination of individual facilities." A number of the revisions incorporated in *HCM 2000* are relevant to travel demand modeling [ref. 5,6]:

Freeways

- LOS thresholds are slightly higher (by 3% to 5%) for LOS "A" through "D," and maximum service flow rates increase by about 10%. LOS "E" values remain unchanged (an example of the above rationale for using "ultimate" rather than "design" capacity).
- Passenger car equivalents (ET) for trucks and buses have been reduced for specific grades, and for rolling and mountainous terrain.

Multilane Highways

- LOS density thresholds are reduced slightly for LOS "A" through "C," and raised slightly for LOS "D." Maximum density for LOS "E" remains unchanged (another argument for favoring "ultimate" over "design" capacity).
- Passenger car equivalents (ET) for trucks and buses have been reduced for specific grades, and for rolling and mountainous terrain.

Two Lane Rural Highways

A completely new methodology is introduced, dividing two lane rural highways into two classes with differing LOS criteria, and permitting analysis both directions of travel combined, or each direction separately.

- Base capacity is increased from 2,800 to 3,200 passenger cars per hour (total in both directions).
- Results are now sensitive to free-flow speed.
- Heavy vehicle and grade adjustment factors have been totally revised.

Urban Arterials (Signalized Intersections)

The Asheville model does not explicitly incorporate node-based capacity or delay (i.e., signalized intersections, 4-way stops, etc.). However, the speeds, capacities, and volume/delay functions associated with urban arterials assume certain underlying intersection characteristics, and signalized intersections are the most critical determinants of urban arterial performance.

- New methodology for treating protected + permitted left turns from a shared lane.
- New saturation flow adjustment factors for bicycles and pedestrians.

- Substitution of computed cycle length for maximum cycle length in planning analysis. Critical v/c ratio is calculated using a saturation flow of 1710 vehicles/hour of green time, rather than 1900.

Corridor and Areawide Analysis

HCM 2000 devotes two new chapters (29 and 30) to the analysis of corridors and large areas, as opposed to individual facilities. Chapter 30, *Areawide Analysis*, provides the methodological basis for the determining roadway capacities in the Asheville Urban Area travel demand model. This chapter recommends assumptions, approximations, and simplifications for the more detailed and precise HCM procedures. This approach is appropriate, considering both the geographic scale and timeframe involved. It is simply not feasible to perform detailed individual analyses on the thousands of links and nodes included in the model, especially when many of the input parameters must be forecast 30 years into the future. The magnitude of uncertainty inherent in the forecasting/modeling process is far greater than any perceived precision gained from more sophisticated (and resource-intensive) analysis techniques.

In effect, Chapter 30 acts as a sensitivity analysis to help identify a manageable number of truly critical variables for determining link capacities and speeds. One of the most useful contributions of this Chapter is a simple taxonomy establishing correspondence between HCM facility types and functional classification. Functional classes do not relate directly to capacity analysis; Exhibit 1 (adapted from *HCM 2000* Exhibit 30-1) relates functional classification to the four basic facility types (by subsystem) used in capacity analysis:

- Freeway (urban and rural),
- Multilane Highway (urban and rural),
- Two-Lane Rural Highway (Class I or II),
- Urban Street (Arterial Classes I, II, III. and IV).

Chapter 30 touches on several other concepts that are critical to this methodology and its application to regional travel demand models, and which bear further emphasis and explanation:

- Capacity is defined by the critical or minimum point in each link, analogous to a bottleneck in a pipeline.
- Free flow speed is estimated based on area type, posted speed limits, local conditions, and specific factors discussed in Chapter 30 (although the detailed methodology described in Chapter 30 was deemed too cumbersome and detailed for this model). A default table (Exhibit 2) was derived as a starting point for the Asheville model.
- Terrain is significant factor in Asheville. The interaction between heavy vehicle percentages and percent grade can substantially lower capacity. This is particularly true on the large number of two-lane highways in the model, where capacity is highly sensitive to the percent of “no passing” zones. The Asheville model assumes “rolling” terrain, with adjustments made as needed to reflect “mountainous” or “level” conditions.
- It is important to correctly convert from PCE capacity (passenger-car equivalents per hour) to mixed-vehicle capacity (vehicles per hour), and to insure that the assumed vehicle mix is consistent with the actual or anticipated vehicle mix.

Exhibit 2 summarizes the basic capacity-related parameters available for each facility type, and identifies any default conditions or typically assumed values. These parameters are useful both in properly classifying a facility and in establishing an accurate capacity.

Exhibit 1: Functional Class – Facility Type Correspondence

Functional Class	Subsystem	Facility Type
Freeway	Freeway	Basic
Ramp (On)	Arterial	Class III (100% green time)
Ramp (Off)	Arterial	Class III (<100% green time)
Ramp (Freeway – Freeway)	Freeway	Basic
Expressway	Urban: Arterial	Class I
	Rural: Multilane Highway	Basic
Divided Arterial	Urban: Arterial	Class I, II, or III
	Rural: Multilane Highway	Basic
Undivided Arterial	Urban: Arterial	Class II, III, or IV
	Rural: Multilane/2-Lane Highway	Basic/Class I
Collector	Urban: Arterial	Class III or IV
	Rural: 2-Lane Highway	Class I or II
Local	Urban: Arterial	Class III or IV
	Rural: 2-Lane Highway	Class II
Centroid Connector	NA	NA

3. INPUT PARAMETERS

This section explains the basic input parameters summarized in Exhibit 2, most of which are reflected in link attribute fields. These parameters are relevant either to all links, or to all the links within the interrupted flow category. More specific parameters and variables are discussed in detail in Section 4, Facility Types.

Te default values assumed for most parameters reflect the fundamental strategic or philosophical approaches underlying the entire model: consistency and simplicity. The default values are intended to represent the <u>best</u> conditions typically found. As with *HCM 2000* methodology, a realistic “ideal” situation is identified, and then reduction factors are applied to reflect conditions that vary significantly from this case. One advantage is that capacity adjustments tend to be in one direction only (reductions) rather than in either direction. Use of this “ideal” (but realistic) basis reduces the potential for unintentionally constricting capacities, thereby over-stating deficiencies and congestion levels. The range of pre-defined capacities is more than adequate to address most situations, and the supporting spreadsheets are designed for easy modification to account for special circumstances. An important objective underlying this approach is reducing the number of decisions necessary, placing the focus instead on significant differences. This avoids a cumbersome process that is difficult to implement consistently, or which yields a lot of capacities that do not differ significantly from each other.

Exhibit 2: Capacity Parameters

CAPACITY - RELATED VARIABLES													
Facility Type	**Freeway**	**Multilane Highway**	**2-Lane Highway**	**Arterial I**	**Arterial II**	**Arterial III**	**Arterial IV**	**Collector**	**Local**	**Freeway On-Ramp**	**Freeway Off-Ramp**	**Freeway-Freeway**	**Centroid Connector**
Posted Speed (mph)	50 - 75 *70 (Rur)* *55 (Urb)*	45 - 60 *70 (Rur)* *55 (Urb)*	40 - 60 *55*	40 - 50 *45*	30 - 40 *35*	25 - 40 *30*	20 - 30 *25*	30 - 45 *35*	25 - 35 *30*	30 - 40 *35*	30 - 40 *35*	40 - 55 *45 (Rur)* *40 (Urb)*	NA
Free Flow Speed (mph)	*55 - 75*	*45 - 65*	*45 - 65*	*50*	*40*	*35*	*35 - 30*	*35*	*35*	*35*	*35*	*55*	NA
Grade	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	Level **Rolling** Mountain	NA
Through Lanes	2, 3, 4, 5	2, 3	1	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2	1	1, 2	1, 2	1, 2	NA
Area Type	Rural Urban	Rural Urban	Rural	Urban	Urban	Urban CBD	Urban CBD	Rural? **Urban** **CBD**	Rural? **Urban** **CBD**	Rural Urban	Rural Urban	Rural Urban	Rural Urban CBD
Trucks	16% (Rur) 8% (Urb)	12% (Rur) 6% (Urb)	18%	4%	3%	2%	2%	2%	2%	8% (Rur) 4% (Urb)	8% (Rur) 4% (Urb)	16% (Rur) 8% (Urb)	NA
LT Bays	NA	Assumed	NA	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed	NA	Assumed	NA	NA
One-Way?	1-Way	1-Way **2-Way**	2-Way	1-Way 2-Way	1-Way 2-Way	1-Way 2-Way	1-Way 2-Way	1-Way 2-Way	1-Way 2-Way	1-Way	1-Way	1-Way	NA
Median	Divided	**Divided** Undivided	Undivided	**Divided** Undivided	**Divided** Undivided	**Divided** Undivided	**Divided** Undivided	Undivided	Undivided	NA	NA	NA	NA

Italics: Indicates value or condition typically assumed.

Bold: Indicates default value or condition.

Speeds

Both link capacity and minimum time paths are highly dependent on free flow speeds (FFS). However, directly determining the actual free flow speeds of every link in the model network is prohibitively difficult, time-consuming, and expensive. In addition, there is the problem of determining free-flow speed for proposed facilities. Therefore, FFS is estimated from a combination of field observation, posted speed limit, design speed, and judgment. Because speed limits are defined values readily available for existing and future roads, they provide a consistent base for estimating FFS. As a default, FFS is typically estimated at 5 mph over the posted speed limit. This value usually corresponds with the design speed of the facility, and can be assumed to correspond with the speed most drivers would be comfortable driving under ideal conditions (no congestion, good weather, no traffic signal delays, etc.). In some cases, such as where speed limits have been lowered substantially, or where steep grades constrain speeds, the FFS requires additional adjustment.

Grades

Grades have a significant impact on capacity, especially on two-lane highways, or where truck percentages are high. For the purposes of this model, “rolling” terrain was assumed (extended grades between and 3% and 5%). Along segments with exceptionally long or steep grades, terrain was treated as “mountainous,” with a resulting decrease in capacity.

Trucks

Factors other than geometrics affect capacity. High truck volumes reduce capacity, since trucks use up more space than passenger cars, obstruct vision, accelerate and turn more slowly, and have lower top speeds on steep uphill grades. Initially, standard truck percentages were assumed for all network links, based on state and national averages for various urban and rural functional classifications. Additional vehicle classification traffic counts were conducted as part of this study, and based on these data, truck percentages on interstates were increased. Between the eastern terminus of I-240 and the I-26 interchange to the west, truck percentages on I-40 and I-240 range from 8% to 16%, with I-40 carrying a higher proportion of trucks. As the interstates become increasingly rural, truck percentages increase from 20% to 24%. This gradual urban-rural transition in truck percentages eliminates the need for a separate suburban classification.

Number of Lanes

The number of through lanes is obviously the basic determinant of capacity. Links are coded with what is judged to be the number of *effective* through lanes in each direction, over the length of the link. The number of through lanes cannot change over a single link; division into two or more links is required. Asymmetrical or unbalanced cross-sections are reflected in the coding. Reversible lanes were not encountered in Asheville, but could be represented by a special field used to designate operational characteristics by time-of-day.

Medians & Left Turn Bays

An important element in determining the capacity of surface streets is their ability to handle left-turning traffic without interfering with through traffic using the same intersection approach leg. Ideal conditions consist of a wide median with adequately sized left-turn bays. However, at level-of-service “E,” a continuous center left-turn lane provides essentially the same capacity as a median, so these two situations are treated as equivalent. Arterial Classes I-IV (as well as multilane highways and freeways) are all assumed to have adequate left-turn treatments, whether provided by a median or by a center turn lane. Adequate left-turn bays are also assumed. On arterials without medians or center turn lanes, capacity is reduced by 5%, assuming adequate left-turn bays are present. If left turn bays are absent or inadequate, capacities are instead reduced by 25%. In the case of multilane highways, lack of a median has the effect of lowering free flow speed and LOS “E“capacity by about 1.6%, an amount that is assumed negligible for modeling purposes.

Collector and local streets are assumed to be undivided, with adequate left turn baysWithout adequate left-turn bays, capacities are reduced 5%.

One-Way/Two-Way Links

Freeways and most divided multilane highways are coded as pairs of one-way links, rather than as a single two-way link. Freeway ramps are coded as one-way links. All other facilities are coded as two-way links, except for streets designated as one-way. The capacity of a one-way street is slightly higher than its two-way equivalent, due primarily to fewer turning movement conflicts at intersections. This is reflected in higher g/C ratios assumed in capacity calculations.

Area Type

Two basic area types are used in the Asheville model: urban and rural. These categories represent either end of a continuum of development intensity/density and traffic composition/concentration. Urban facilities are characterized by less extreme peaking of traffic by time-of-day and direction, and by lower truck percentages. Rural facilities tend to have higher design and travel speeds, and more interruptions to traffic flow. The designation of "rural" or "urban" does not in itself change the capacity of a facility. Instead, capacity is determined by corresponding parameters that are consistent with the area type. (such as interchange or signal spacing, k factors and D factors, free flow speeds, truck percentages, etc.) To avoid abrupt and arbitrary capacity changes at an urban-rural boundary, judgment was used to adjust the relevant capacity-determining parameters in transitional (suburban) areas, which in turn alter the capacity. This approach eliminates the need to create one or more separate suburban area types, and to make ever more subtle distinctions in deciding which category fits which road.

Within the urban area, a special subarea was defined, corresponding with the central business district (CBD). This distinction is needed to capture the significant impacts of higher levels of on-street parking, pedestrian crossings, and bus stopping, combined with more frequent intersections and traffic control devices.

Certain classes of facilities (freeways and multilane highways) can be found in any area type. This is true because, to some extent, access control separates these facilities from direct contact with the surrounding area. Other classes of facilities are much more sensitive to their immediate surroundings, and may not typically exist in a particular area type. Urban arterials, by definition are urban, while two-lane highways (except under extremely unusual conditions), are not. Similarly, the CBD area type is relevant only to a subset of streets (local, collector, and lower-level arterial classifications).

4. FACILITY TYPES

Freeway Subsystem

Exhibits 3 though 5 summarize the input parameters used in calculating freeway capacities. The values in Exhibit 3 are common to all freeways. Exhibits 4 and 5 identify differences in assumptions by area type and by terrain (level, rolling, and mountainous).

Exhibits 6 – 11 are tabular summaries of urban and rural freeway capacities for standard free-flow speeds, the three terrain types, and three levels of heavy vehicle percentages.

Exhibits 12 – 15 graphically depict relationships among FFS, terrain, and number of lanes in determining capacities for typical urban and rural freeway segments, assuming moderate truck percentages. Exhibits 16 and 17 similarly demonstrate the effects of different assumed truck percentages on capacities of urban, 4-lane freeway segments of various grades and free-flow speeds.

Obviously, capacities are most sensitive to the number of lanes, followed by terrain and truck percentage (these two variables interact, especially when steeper grades are involved). The other significant variable is free flow speed.

Exhibit 3: Assumed Constants for All Freeways

Parameter	Value or Condition	Adjustment Factor
Free Flow Speed	75 – 55 mph	-
Service Volume*	2400 – 2250 vph	-
Directional Distribution	0.60	-
Lane Width	12 feet	1.000
Lateral Clearance	6 feet	1.000
Driver Population	Commuter	1.000

*Dependent on FFS.

Exhibit 4: Assumptions for Freeways (Urban vs. Rural)

Parameter	Value or Condition	Adjustment Factor
K Factor: Urban	0.09	-
K Factor: Rural	0.10	-
Interchange Spacing: Urban	$\geq$ 1.00 miles	1.000
Interchange Spacing: Rural	$\geq$ 1.25 miles	1.000
Heavy Vehicles: Urban	8% - 16%	varies
Heavy Vehicles: Rural	16% - 24%	varies
Peak Hour Factor: Urban	0.92	0.920
Peak Hour Factor: Rural	0.88	0.880

Exhibit 5: Freeway Heavy Vehicle Factors by Terrain Type

Parameter	Value or Condition	Adjustment Factor
Heavy Vehicle Factor: Urban	Level	0.960 - 0.930
	Rolling	0.890 - 0.810
	Mountainous	0.780 - 0.640
Heavy Vehicle Factor: Rural	Level	0.930 – 0.890
	Rolling	0.810 – 0.740
	Mountainous	0.640 – 0.540

Exhibit 6: Urban Freeway Capacities (Low Trucks: 8% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	4,250	3,940	3,450	78,700	73,000	63,900
3	75-70	2,400	6,370	5,910	5,180	118,000	109,400	95,900
4	75-70	2,400	8,490	7,890	6,900	157,200	146,100	127,800
5	75-70	2,400	10,620	9,860	8,630	196,700	182,600	159,800
2	65	2,350	4,160	3,860	3,380	77,100	71,500	62,600
3	65	2,350	6,240	5,790	5,070	115,500	107,100	93,900
4	65	2,350	8,320	7,720	6,760	153,900	143,100	125,100
5	65	2,350	10,390	9,650	8,450	192,600	178,800	156,500
2	60	2,300	4,070	3,780	3,310	75,400	70,000	61,300
3	60	2,300	6,100	5,670	4,960	113,000	105,000	91,900
4	60	2,300	8,140	7,560	6,610	150,700	140,000	122,400
5	60	2,300	10,170	9,450	8,270	188,300	175,000	153,100
2	55	2,250	3,980	3,700	3,230	73,700	68,500	59,800
3	55	2,250	5,970	5,540	4,850	110,600	102,600	89,800
4	55	2,250	7,960	7,390	6,470	147,400	136,900	119,800
5	55	2,250	9,950	9,240	8,090	184,300	171,100	149,800

Exhibit 7: Rural Freeway Capacities (Low Trucks: 16% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	3,910	3,410	2,710	65,200	56,800	45,200
3	75-70	2,400	5,870	5,110	4,060	97,800	85,200	67,700
4	75-70	2,400	7,820	6,810	5,420	130,300	113,500	90,300
5	75-70	2,400	9,780	8,520	6,770	163,000	142,000	112,800
2	65	2,350	3,830	3,340	2,650	63,800	55,700	44,200
3	65	2,350	5,740	5,000	3,980	95,700	83,300	66,300
4	65	2,350	7,660	6,670	5,300	127,700	111,200	88,300
5	65	2,350	9,570	8,340	6,630	159,500	139,000	110,500
2	60	2,300	3,750	3,260	2,590	62,400	54,500	43,300
3	60	2,300	5,620	4,900	3,890	93,700	81,500	64,900
4	60	2,300	7,500	6,530	5,190	125,000	108,800	86,400
5	60	2,300	9,370	8,160	6,490	156,100	136,000	108,100
2	55	2,250	3,670	3,190	2,540	61,100	53,300	42,400
3	55	2,250	5,500	4,790	3,810	91,700	79,800	63,500
4	55	2,250	7,330	6,390	5,080	122,300	106,500	84,600
5	55	2,250	9,170	7,980	6,350	152,800	133,100	105,800

Exhibit 8: Urban Freeway Capacities (Moderate Trucks: 12% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	4,170	3,740	3,110	77,200	69,300	57,600
3	75-70	2,400	6,250	5,610	4,660	115,700	103,900	86,300
4	75-70	2,400	8,330	7,480	6,220	154,300	138,500	115,200
5	75-70	2,400	10,420	9,360	7,770	193,000	173,300	143,900
2	65	2,350	4,080	3,660	3,050	75,600	67,900	56,400
3	65	2,350	6,120	5,500	4,570	113,300	101,700	84,500
4	65	2,350	8,160	7,330	6,090	151,100	135,600	112,800
5	65	2,350	10,200	9,160	7,610	189,000	169,700	140,900
2	60	2,300	3,990	3,590	2,980	73,900	66,500	55,200
3	60	2,300	5,990	5,380	4,470	110,900	99,600	82,800
4	60	2,300	7,980	7,170	5,960	147,800	132,800	110,400
5	60	2,300	9,980	8,970	7,450	184,800	166,100	138,000
2	55	2,250	3,910	3,510	2,920	72,400	65,000	54,100
3	55	2,250	5,860	5,260	4,370	108,500	97,400	80,900
4	55	2,250	7,810	7,020	5,830	144,600	130,000	108,000
5	55	2,250	9,760	8,770	7,290	180,700	162,400	135,000

Exhibit 9: Rural Freeway Capacities (Moderate Trucks: 20% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	3,840	3,250	2,480	64,000	54,200	41,300
3	75-70	2,400	5,760	4,870	3,730	96,000	81,200	62,200
4	75-70	2,400	7,680	6,500	4,970	128,000	108,300	82,800
5	75-70	2,400	9,600	8,120	6,210	160,000	135,300	103,500
2	65	2,350	3,760	3,180	2,430	62,700	53,000	40,500
3	65	2,350	5,640	4,770	3,650	94,000	79,500	60,800
4	65	2,350	7,520	6,360	4,870	125,300	106,000	81,200
5	65	2,350	9,400	7,950	6,080	156,700	132,500	101,300
2	60	2,300	3,680	3,110	2,380	61,400	51,900	39,600
3	60	2,300	5,520	4,670	3,570	92,000	77,800	59,500
4	60	2,300	7,360	6,230	4,760	122,600	103,700	79,500
5	60	2,300	9,200	7,780	5,950	153,400	129,700	99,100
2	55	2,250	3,600	3,050	2,330	60,100	50,800	38,800
3	55	2,250	5,400	4,570	3,490	90,000	76,100	58,200
4	55	2,250	7,200	6,090	4,660	120,000	101,500	77,800
5	55	2,250	9,000	7,620	5,820	150,100	126,900	97,000

Exhibit 10: Urban Freeway Capacities (High Trucks: 16% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	4,090	3,560	2,830	75,700	65,900	52,400
3	75-70	2,400	6,130	5,340	4,250	113,500	98,900	78,700
4	75-70	2,400	8,180	7,120	5,660	151,500	131,900	104,800
5	75-70	2,400	10,220	8,900	7,080	189,300	164,800	131,100
2	65	2,350	4,000	3,490	2,770	74,100	64,500	51,300
3	65	2,350	6,010	5,230	4,160	111,100	96,800	77,100
4	65	2,350	8,010	6,970	5,540	148,300	129,200	102,600
5	65	2,350	10,010	8,720	6,930	185,400	161,400	128,400
2	60	2,300	3,920	3,410	2,710	72,600	63,100	50,200
3	60	2,300	5,880	5,120	4,070	108,900	94,800	75,400
4	60	2,300	7,840	6,830	5,430	145,200	126,500	100,600
5	60	2,300	9,800	8,530	6,780	181,500	158,000	125,600
2	55	2,250	3,830	3,340	2,650	70,900	61,900	49,100
3	55	2,250	5,750	5,010	3,980	106,500	92,800	73,700
4	55	2,250	7,670	6,680	5,310	142,000	123,700	98,300
5	55	2,250	9,580	8,350	6,630	177,400	154,600	122,800

Exhibit 11: Rural Freeway Capacities (High Trucks: 24% heavy vehicles)

			1-Way Hourly			2-Way Daily		
# Lanes	FFS	SV	Level	Rolling	Mountain	Level	Rolling	Mountain
2	75-70	2,400	3,770	3,110	2,300	62,800	51,800	38,300
3	75-70	2,400	5,660	4,660	3,440	94,300	77,700	57,300
4	75-70	2,400	7,540	6,210	4,590	125,700	103,500	76,500
5	75-70	2,400	9,430	7,760	5,740	157,200	129,300	95,700
2	65	2,350	3,690	3,040	2,250	61,500	50,700	37,500
3	65	2,350	5,540	4,560	3,370	92,300	76,000	56,200
4	65	2,350	7,390	6,080	4,500	123,200	101,300	75,000
5	65	2,350	9,230	7,600	5,620	153,800	126,700	93,700
2	60	2,300	3,610	2,980	2,200	60,200	49,600	36,700
3	60	2,300	5,420	4,460	3,300	90,300	74,400	55,000
4	60	2,300	7,230	5,950	4,400	120,600	99,100	73,400
5	60	2,300	9,040	7,440	5,500	150,500	124,000	91,700
2	55	2,250	3,540	2,910	2,150	58,900	48,500	35,900
3	55	2,250	5,300	4,370	3,230	88,400	72,800	53,800
4	55	2,250	7,070	5,820	4,300	118,000	97,000	71,800
5	55	2,250	8,840	7,280	5,380	147,300	121,400	89,700

Exhibit 12: Urban Freeway Capacities by Number of Lanes and FFS (for 12% heavy vehicles)

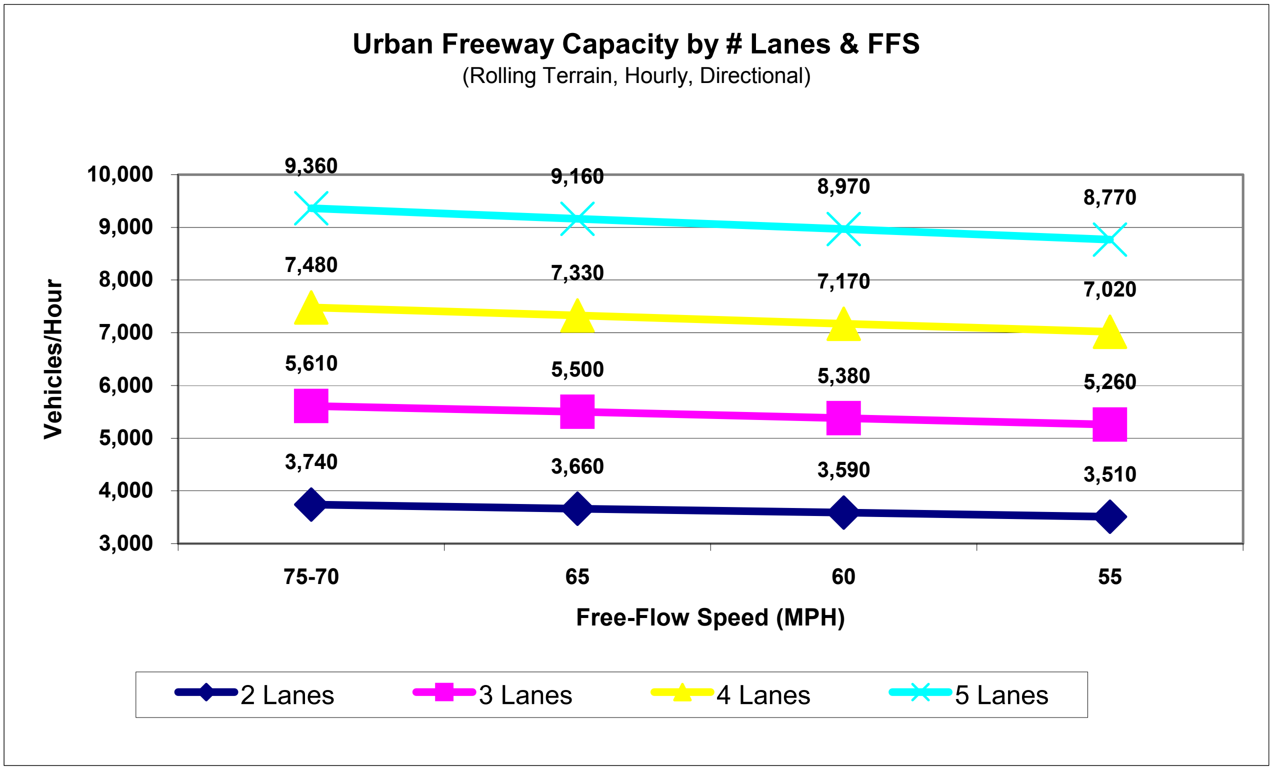


Exhibit 13: Rural Freeway Capacities by Number of Lanes and FFS (for 20% heavy vehicles)

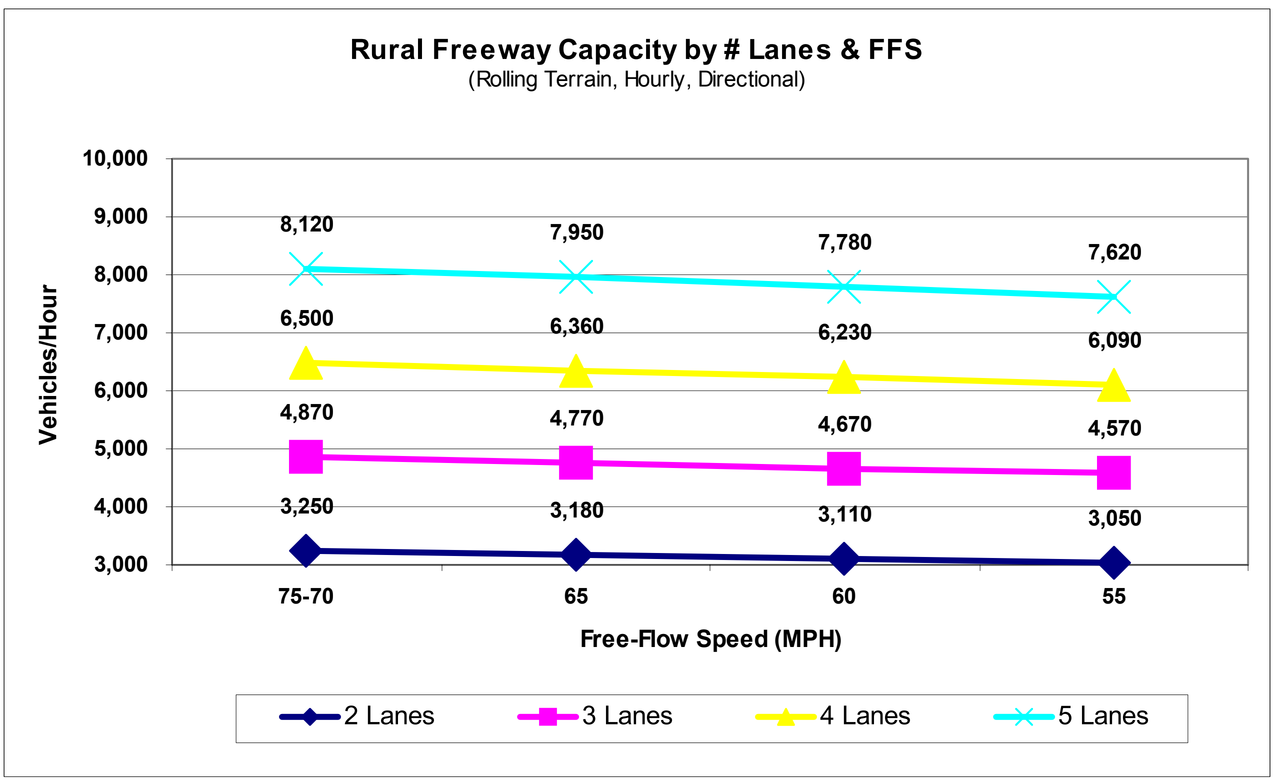


Exhibit 14: 4-Lane Urban Freeway Capacities by FFS and Terrain (for 12% heavy vehicles)

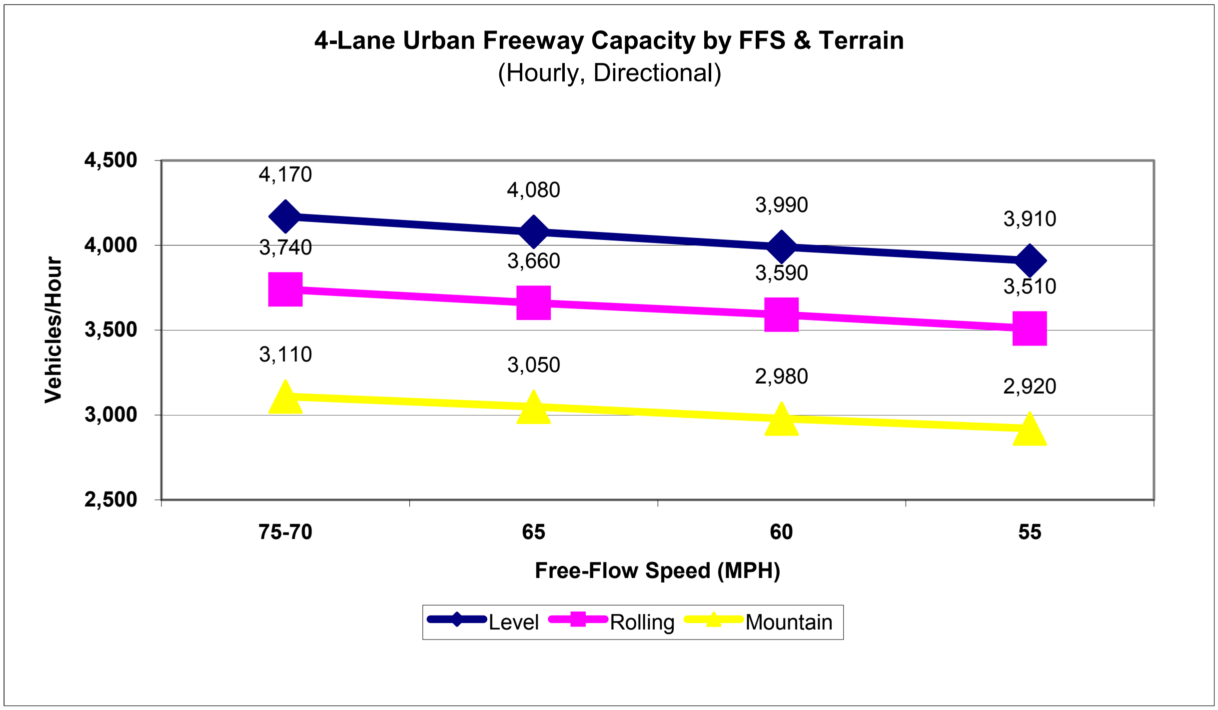


Exhibit 15: 4-Lane Rural Freeway Capacities by FFS and Terrain (for 20% heavy vehicles)

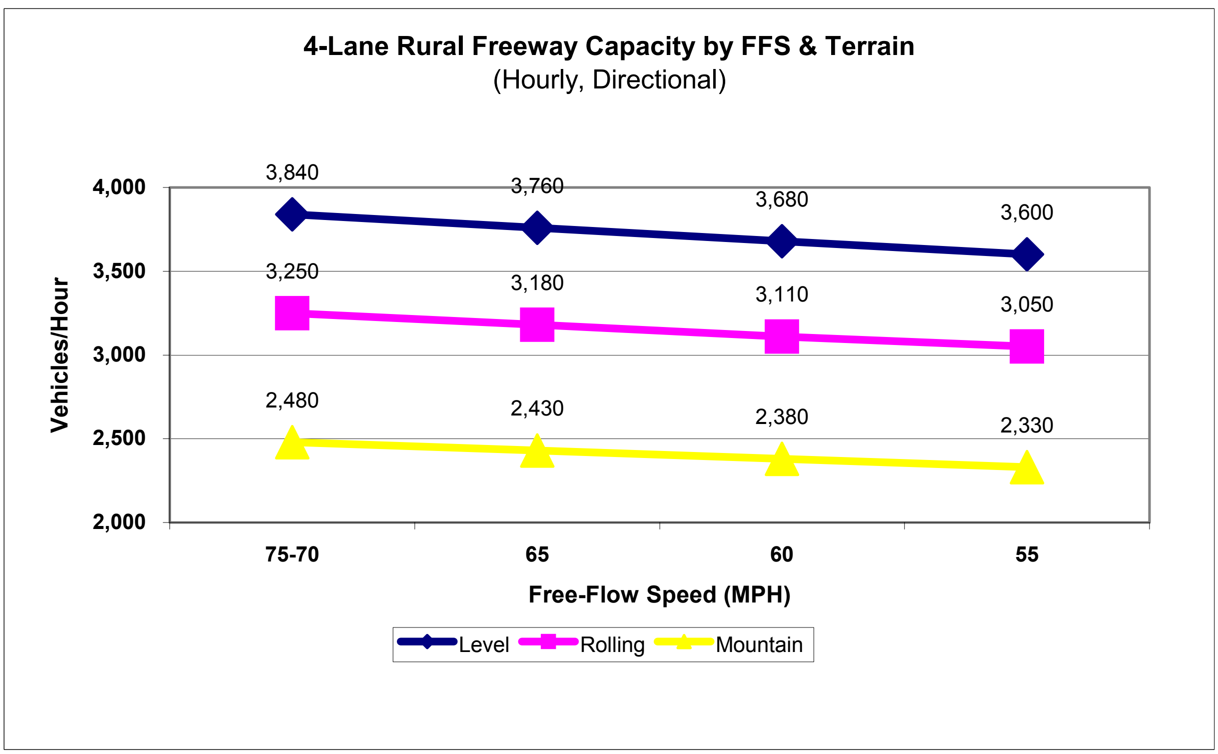


Exhibit 16: 4-Lane Urban Freeway Capacities by %Trucks and Terrain

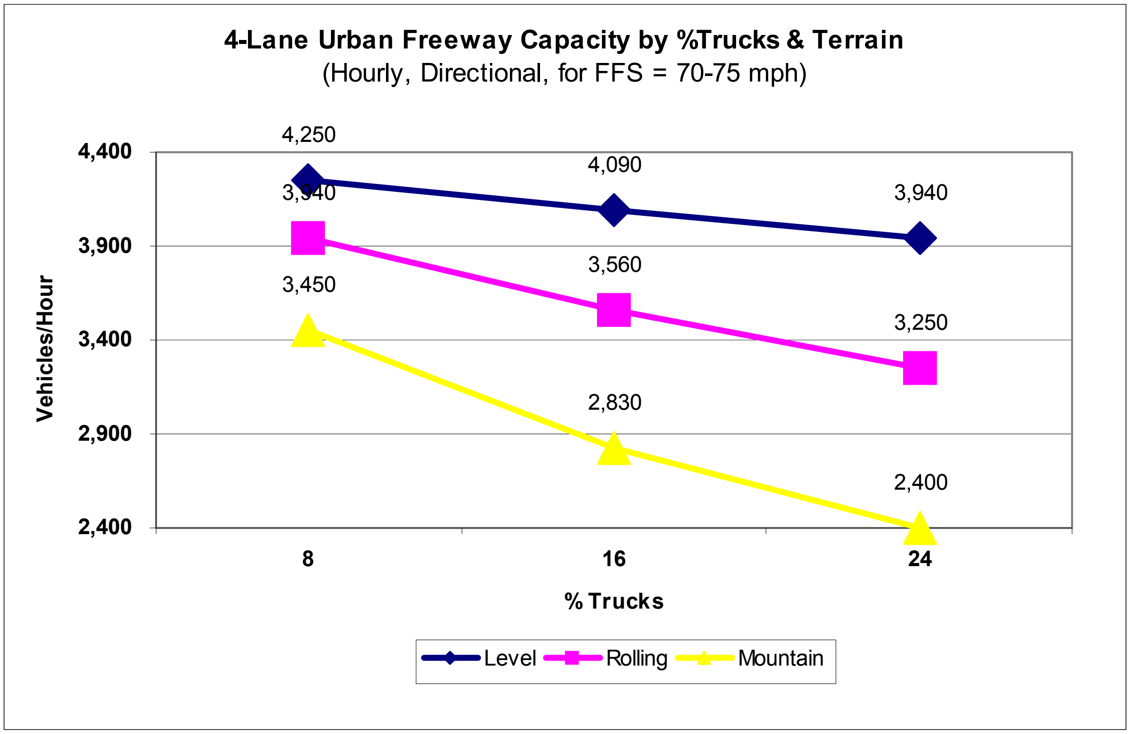
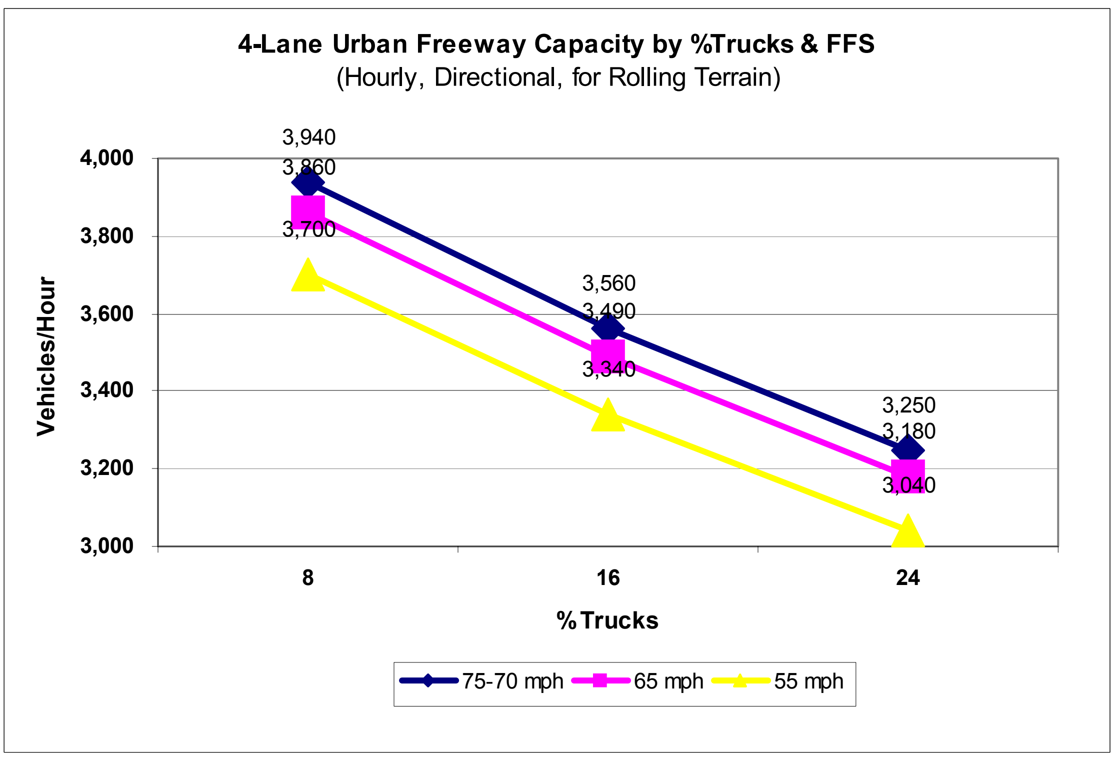


Exhibit 17: 4-Lane Urban Freeway Capacities by %Trucks and FFS



APPENDIX C

ROADWAY CONGESTION INDEX

Contained herein are portions of Appendix B to the *2003 Urban Mobility Study* developed by the Texas Transportation Institute (http://mobility.tamu.edu/ums/report/) that detail the methodology for calculating a Regional Congestion Index (RCI) as well as a computation of the RCI for the City of Greensboro Urban Area.

Exhibit B-5. Percentage of Daily Travel Used in Delay Estimation Procedure for 2002 Annual Report

Urban Area	Roadway Congestion Index	% of Daily Travel in Congested Conditions
Los Angeles, CA	1.56	50.0
San Francisco-Oakland, CA	1.41	50.0
San Jose, CA	1.36	49.3
San Diego, CA	1.35	49.2
Chicago, IL-Northwestern, IN	1.34	49.0
Washington, DC-MD-VA	1.34	49.0
Atlanta, GA	1.33	48.8
Boston, MA	1.31	48.5
San Bernardino-Riverside, CA	1.30	48.3
Miami-Hialeah, FL	1.29	48.2
Phoenix, AZ	1.29	48.2
Denver, CO	1.28	48.0
Ft. Lauderdale-Hollywood-Pompano Bch, FL	1.28	48.0
Portland-Vancouver, OR-WA	1.28	48.0
Sacramento, CA	1.28	48.0
Tacoma, WA	1.26	47.7
Minneapolis-St. Paul, MN	1.25	47.5
W Palm Bch-Boca Raton-Delray Bch, FL	1.25	47.5
Detroit, MI	1.24	47.3
Seattle-Everett, WA	1.23	47.2
Las Vegas, NV	1.20	46.7
Houston, TX	1.19	46.5
Indianapolis, IN	1.19	46.5
Austin, TX	1.17	46.2
Charlotte, NC	1.17	46.2
Tampa-St Petersburg-Clearwater, FL	1.16	46.0
New York, NY-Northeastern, NJ	1.15	45.8
Baltimore, MD	1.14	45.7
Orlando, FL	1.14	45.7
Cincinnati, OH-KY	1.12	45.3
Dallas-Fort Worth, TX	1.12	45.3
Philadelphia, PA-NJ	1.11	45.2
Tucson, AZ	1.09	44.5
Columbus, OH	1.08	44.0
Louisville, KY-IN	1.08	44.0
Milwaukee, WI	1.08	44.0
Salt Lake City, UT	1.08	44.0
Albuquerque, NM	1.05	42.5
Honolulu, HI	1.04	42.0
San Antonio, TX	1.04	42.0
Memphis, TN-AR-MS	1.03	41.5
Nashville, TN	1.03	41.5
Jacksonville, FL	1.02	41.0
St. Louis, MO-IL	1.02	41.0
Birmingham, AL	1.00	40.0
Providence-Pawtucket, RI-MA	1.00	40.0
El Paso, TX-NM	0.99	39.5
Hartford-Middletown, CT	0.98	39.0
Fresno, CA	0.97	38.5
New Orleans, LA	0.97	38.5
Norfolk-Newport News-Virginia Beach, VA	0.96	38.0
Charleston, SC	0.95	37.5
Fort Myers-Cape Coral, FL	0.95	37.5
Cleveland, OH	0.94	37.0
Eugene-Springfield, OR	0.92	36.0
Omaha, NE-IA	0.92	36.0
Pensacola, FL	0.91	35.5
Tulsa, OK	0.88	33.7
Colorado Springs, CO	0.87	33.0
Salem, OR	0.87	33.0
Beaumont, TX	0.86	32.3
Oklahoma City, OK	0.86	32.3
Boulder, CO	0.84	31.0
Kansas City, MO-KS	0.84	31.0
Richmond, VA	0.83	30.3
Spokane, WA	0.81	29.0
Albany-Schenectady-Troy, NY	0.80	28.3
Rochester, NY	0.80	28.3
Brownsville, TX	0.79	27.7
Pittsburgh, PA	0.78	27.0
Bakersfield, CA	0.77	26.3
Buffalo-Niagara Falls, NY	0.75	25.0
Corpus Christi, TX	0.71	23.7
Laredo, TX	0.67	22.3
Anchorage, AK	0.65	21.7

ROADWAY CONGESTION INDEX

Urban roadway congestion levels are estimated using a formula that measures the density of traffic. Average daily travel volume per lane on freeways and principal arterial streets are estimated using areawide estimates of vehicle-miles of travel (VMT) and lane-miles of roadway (Ln-Mi). The resulting ratios are combined using the amount of travel on each portion of the system so that the combined index measures conditions on the freeway and principal arterial street systems. This variable weighting factor allows comparisons between areas such as Phoenix, where principal arterial streets carry 50% the amount of travel of freeways, and cities such as Portland where the ratio is reversed.

The traffic density ratio is divided by a similar ratio that represents congestion for a system with the same mix of freeway and street volume. While it may appear that the travel volume factors (e.g., freeway VMT) on the top and bottom of the equation cancel each other, a sample calculation should satisfy the reader that this is not the case.

Equation 17 illustrates the factors used in the congestion index. The resulting ratio indicates an undesirable level of areawide congestion if a value greater than or equal to 1.0 is obtained.

$$\begin{array}{c}\text{Roadway}\\ \text{Congestion}\\ \text{Index}\end{array} = \frac{\dfrac{\text{Freeway}}{\text{VMT/Ln.-Mi.}} \times \dfrac{\text{Freeway}}{\text{VMT}} + \dfrac{\text{Prin Art Str}}{\text{VMT/Ln-Mi.}} \times \dfrac{\text{Prin Art Str}}{\text{VMT}}}{14{,}000 \times \dfrac{\text{Freeway}}{\text{VMT}} + 5{,}500 \times \dfrac{\text{Prin Art Str}}{\text{VMT}}} \qquad \text{(Eq. 17)}$$

An Illustration of Travel Conditions When an Urban Area RCI Equals 1.0

The congestion index is a macroscopic measure which does not account for local bottlenecks or variations in travel patterns that affect time of travel or origin-destination combinations. It also does not include the effect of improvements such as freeway entrance ramp signals, or of treatments designed to give a travel speed advantage to transit and carpool riders.

- ♦ Typical commute time not more than 25% longer than off-peak travel time.
- ♦ Slower moving traffic during the peak period on the freeways, but not sustained stop-and-go conditions.
- ♦ Moderate congestion for not more than 1 1/2 to 2 hours during each peak-period.
- ♦ Wait through one or two red lights at heavily traveled intersections, but not 3 or 4.

- The RCI includes roadway expansion, demand management, and vehicle travel reduction programs.
- The RCI does not include the effect of operations improvements (e.g., clearing accidents quickly, regional traffic signal coordination), person movement efficiencies (e.g., bus and carpool lanes) or transit improvements (e.g., priority at traffic signals).
- The RCI does not address situations where a traffic bottleneck means much less capacity than demand (e.g., a narrow bridge or tunnel crossing a harbor or river), or missing capacity due to a gap in the system.
- The congestion study averages all the developments within an urban area; there will be locations where congestion is much worse or better than average.

	Freeway Lane Miles	Freeway VMT	Freeway VMT/Ln miles	PA Lane Miles	PA VMT	PA VMT/Ln Miles	RCI
Base Yr	283.0	710585.0	2511.3	1789.8	756572.2	422.7	1.49
Future Yr	489.7	731188.5	1493.2	1904.3	907442.5	476.5	1.00

$$\text{Base Year RCI} = \frac{(2{,}511.3 * 710{,}585) + (422.7 * 756{,}572.2)}{(14{,}000 * 710{,}585) + (5{,}500 * 756{,}572.2)} = 1.49$$

$$\text{Future Year RCI} = \frac{(1{,}493.2 * 731{,}188.5) + (476.5 * 907{,}442.5)}{(14{,}000 * 731{,}188.5) + (5{,}500 * 907{,}442.5)} = 1.00$$